

06/15/99 JCS04 U.S. PTO 0933379 064599

A

UTILITY PATENT APPLICATION TRANSMITTAL

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Attorney Docket No. 189405  
First Named Inventor Hagenbuch  
Express Mail No. EL305737484US

JCS03 U.S. PTO 09/333379

06/15/99

APPLICATION ELEMENTS

ACCOMPANYING APPLICATION PARTS

- 1. ☒ Transmittal Form with Fee
- 2. ☒ Specification (including claims and abstract) [Total Pages 25]
- 3. ☒ Drawings [Total Sheets 24]
- 4. ☐ Combined Declaration and Power of Attorney [Total Pages ]
  - a. ☐ Newly executed
  - b. ☐ Copy from prior application

[Note Box 5 below]

  - i. ☐ Deletion of Inventor(s) Signed statement attached deleting inventor(s) named in the prior application
- 5. ☐ Incorporation by Reference: The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
- 6. ☐ Microfiche Computer Program
- 7. ☐ Nucleotide and/or Amino Acid Sequence Submission
  - a. ☐ Computer Readable Copy
  - b. ☐ Paper Copy
  - c. ☐ Statement verifying above copies

- 8. ☐ Assignment Papers
- 9. ☐ Power of Attorney
- 10. ☐ English Translation Document (if applicable)
- 11. ☐ Information Disclosure Statement (IDS)
  - ☐ PTO-1449 Form
  - ☐ Copies of IDS Citations
- 12. ☐ Preliminary Amendment
- 13. ☒ Return Receipt Postcard (Should be specifically itemized)
- 14. ☒ Small Entity Statement(s)
  - ☐ Enclosed
  - ☐ Statement filed in prior application; status still proper and desired
- 15. ☐ Certified Copy of Priority Document(s)
- 16. ☒ Other: Application Cover Sheets

- 17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information in (a) and (b) below:
  - (a) ☐ Continuation ☐ Divisional ☐ Continuation-in-part of prior application Serial No. \_\_\_\_\_
  - (b) Preliminary Amendment: Relate Back - 35 USC 120. The Commissioner is requested to amend the specification by inserting the following sentence before the first line:  
"This is a ☐ continuation ☐ divisional of copending application(s)  
☐ Serial No. \_\_\_\_\_, filed on \_\_\_\_\_  
☐ International Application, filed on \_\_\_\_\_, and which designates the U.S."

APPLICATION FEES				
BASIC FEE				\$760.00
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total Claims	20 -20=	0	x \$18.00	\$ 0
Independent Claims	1 - 3=	0	x \$78.00	\$ 0
<input type="checkbox"/> Multiple Dependent Claims(s) if applicable			+ \$260.00	\$ 0
Total of above calculations =				\$760.00
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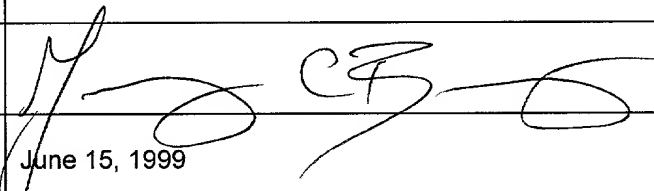
## UTILITY PATENT APPLICATION TRANSMITTAL

Attorney Docket No. 189405

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20. ☒ A check in the amount of \$380.00 is enclosed.
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- a. ☒ Fees required under 37 CFR 1.16.
  - b. ☒ Fees required under 37 CFR 1.17.
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22. ☒ The Commissioner is hereby generally authorized under 37 CFR 1.136(a)(3) to treat any future reply in this or any related application filed pursuant to 37 CFR 1.53 requiring an extension of time as incorporating a request therefor, and the Commissioner is hereby specifically authorized to charge Deposit Account No. 12-1216 for any fee that may be due in connection with such a request for an extension of time.

## 23. CORRESPONDENCE ADDRESS

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Date	June 15, 1999

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Elizabeth Yi		June 15, 1999
Name of Person Signing	Signature	Date

# APPLICATION FOR LETTERS PATENT

Applicant(s): LeRoy G. Hagenbuch , Philip T. Brinkman

Title: PROCESS FOR THREE-DIMENSIONAL MODELING  
AND DESIGN OF OFF-HIGHWAY DUMP BODIES

Serial No. \_\_\_\_\_ Filed \_\_\_\_\_

Group No. \_\_\_\_\_

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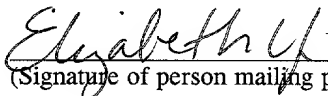
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Elizabeth Yi

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Attorney Docket No.

189405

**PATENT APPLICATION**

Invention Title:

PROCESS FOR THREE-DIMENSIONAL MODELING AND DESIGN OF OFF-HIGHWAY DUMP BODIES

Inventors:

LeRoy G. Hagenbuch	U.S.A.	Peoria	Illinois
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INVENTOR'S NAME	CITIZENSHIP	CITY OF RESIDENCE	STATE or FOREIGN COUNTRY
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Be it known that the inventor(s) listed above have invented a certain new and useful invention with the title shown above of which the following is a specification.

6579-666666

**PROCESS FOR THREE-DIMENSIONAL MODELING  
AND DESIGN OF OFF-HIGHWAY DUMP BODIES**

**FIELD OF THE INVENTION**

5       The present invention relates generally to heavy-duty off-highway trucks, and more particularly to a process for designing an off-highway truck dump body.

**BACKGROUND OF THE INVENTION**

10       In mining and construction environments, heavy-duty off-highway trucks are used to haul a variety of materials such as, for example, coal, rock, ore, and overburden materials. Such heavy-duty off-highway trucks generally comprise a truck chassis or frame which  
15       supports a dump body for receiving and carrying a load. In order to ensure that the dump body is properly balanced, the dump body should be designed based on an anticipated load distribution of the material carried on the truck chassis or frame. More specifically, the truck  
20       chassis anticipates a particular optimal location on the chassis where the center of gravity of the load carried in the dump body should be positioned.

Trucks with dump bodies which are often sold by the original equipment manufacturers have dump bodies  
25       designed around an assumed load configuration or load profile. In designing these dump bodies, however, the load profile which is used to size the body is based on a theoretical material angle of repose or load heap of the material irrespective of material cohesiveness,  
30       individual material heaping characteristics or material gradation. For example, in designing a dump body for

overburden, a theoretical material heap of 2:1 (or a different S.A.E. 2:1 heap) is often assumed.

Historically, off-highway truck manufacturers have been unable to reach a consensus with regards to the theoretical load heaps or configurations, let alone any consensus on the individual hauled material characteristics that should be used to design the dump bodies. As evidenced by their commercially available literature, some off-highway truck manufacturers use theoretical material heap profiles based on standards promulgated by the Society of Automotive Engineers (S.A.E. J 1363 Jan. 1985) while others use their own heap profiles. Moreover, many off-highway truck manufacturers have over time alternated between using various different theoretical load heap profiles or configurations to design their dump bodies.

Off-highway truck manufacturers use these theoretical load heap profiles so that they are able to mass produce their dump bodies. However, the theoretical load heap, and the resulting theoretical load profiles, which the truck manufacturers use to design their dump bodies ignore a number of factors. For example, theoretical load profiles do not take into account the particular material characteristics of the material being loaded and hauled. In addition, theoretical load profiles do not take into account the corner voids which occur when a load is placed in the dump body. In particular, since the material is loaded from overhead into the dump body, the material tends to try to form a generally conical shape in the dump body. Because the load conforms to a generally conical shape, voids are created in the corners of the dump body where no material is present. The theoretical load profiles as used by truck manufacturers ignore these corner voids.

Additionally, field loading/haulage conditions impact the actual angles of repose that the loaded material forms in the dump body. In the loading process, material on its own flows to a natural angle of repose, however, in the loading process as the loading equipment pushes/pulls and rests on the material being loaded an imposed material angle of repose results. For instance, the method by which the material is actually loaded into the dump body, e.g. using a front-end loader or a shovel, can impact the ultimate actual profile of the load in the body. Other material characteristics such as the cohesiveness, gradation, size and consistency of the material (e.g., ore, overburden, clay, etc.) also impacts the actual load profile. Accordingly, because of differences in the materials and field loading and haulage conditions, the actual load profile or configuration of given materials in the dump body at different sites can vary extensively.

As a result, the mass-produced dump bodies supplied by off-highway truck manufacturers which are based on a theoretical material load profile are often improperly matched for a particular material haulage application. For example, the dump body may be inadvertently designed such that the dump body size and resultant load is either undersized/underloaded or oversized/overloaded and that the corresponding center of gravity of the actual load is significantly offset from where it should be placed, based on the design of the truck chassis. This causes incorrect truck loading and improper truck utilization with uneven loading of the truck chassis leading to uneven or offset frame loading, which can potentially result in truck chassis problems including uneven tire wear which often requires premature replacement of the tires; and potentially poor vehicle operating stability. As will be appreciated, since the trucks themselves and

the tires used on these types of off-highway trucks are extremely costly, potential truck chassis repair and premature replacement of tires significantly increases the operating expenses associated with material haulage.

5 Likewise, depending on how the actual material and material heap varies from a theoretical material load profile, the dump body can be either too large or too small resulting in the truck chassis carrying loads which are both improperly placed on the truck frame and  
10 significantly heavier or lighter than intended. An improperly designed body which is too small to carry the intended load can lead to spillage of the load over the sides and off the rear end of the body resulting in significant under utilization of the truck. If side/rear  
15 spillage occurs during transport, it can result in tire damage and tire ruptures particularly on the following trucks. While too large of a body for the intended load can result in extreme truck overloads or if the load is limited to the correct load amount in the dump body, the  
20 load may often be improperly placed in the dump body leading to poor truck stability and individual truck chassis component overloads.

#### **OBJECTS AND SUMMARY OF THE INVENTION**

25 Accordingly, in view of the foregoing, a general object of the invention is to provide a dump body which is designed for specific field operating environments.

A related object is to provide a method for designing off-highway dump bodies which more accurately takes into  
30 account actual field conditions.

A more specific object is to provide a process for three-dimensional modeling of required dump body loads and the related design of dump bodies based on actual field conditions at particular sites.



These and other features and advantages of the invention will be more readily apparent upon reading the following description of a preferred exemplary embodiment of the invention and upon reference to the accompanying drawings wherein:

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIGS. 1-7 are side views and a rear view (FIG. 6) of a heavy-duty, off-highway truck illustrating a portion of an exemplary sequence of process steps for designing a dump body for the truck in accordance with the present invention.

FIG. 8A is a side view of a dump body (outlined in triple solid lines) and a material heap (outline in broken lines) illustrating a process step in the sequence of steps for developing a three-dimensional heaped material load profile based on data collected from a specific haulage environment for use in the dump body design process of the present invention.

FIG. 8B is a rear view of the dump body (outlined in triple solid lines) and the material heap (outlined in broken lines) of FIG. 8A illustrating a process step in the sequence of steps for developing the three-dimensional heaped load profile.

FIG. 9 is top view of the dump body and material heap of FIGS. 8A and 8B illustrating in part how the corners of the heaped load are modeled based on an incremental blending of the side angles of material repose to the front and rear angles of material repose to develop the three-dimensional modeled material heap profile.

FIGS. 10a and 10b are top views of the dump body and material heap of FIGS. 8A and 8B illustrating in part how the corners of the heaped load are modeled based on an incremental blending of the side angles of material repose

to the front and rear angles of material repose to develop the three-dimensional modeled material heap profile.

FIGS. 10c and 11 are perspective views of the dump body and material heap of FIGS. 8A and 8B illustrating in part how the corners of the heaped load are modeled based on an incremental blending of the side angles of material repose to the front and rear angles of material repose to develop the three-dimensional modeled material heap profile.

FIG. 12 is a side view of the dump body and material heap of FIGS. 8A and 8B illustrating in part how the corners of the heaped load are modeled based on an incremental blending of the side angles of material repose to the front and rear angles of material repose to develop the three-dimensional modeled material heap profile.

FIG. 13 is a perspective view of the dump body and material heap of FIG. 8A and 8B illustrating how the corners of the heaped load are modeled based on an incremental blending of the side angles of material repose to the front and rear angles of material repose to develop the three-dimensional modeled material heap profile.

FIG. 14 is a perspective view of the final three-dimensional modeled material heap profile for use in the dump body design process of the present invention.

FIG. 15 is a perspective view of the three-dimensional modeled material heap profile of FIG. 14 in the dump body of FIGS. 8A and 8B.

FIG. 16 is a side view of the off-highway truck of FIGS. 1-7 having the dump body and material heap profile of FIG. 15 illustrating a further step in the dump body design process of the present invention.

FIG. 17 is a side view illustrating the final design of the dump body.

FIGS. 18a-b are a flow diagram of an exemplary embodiment of the design process of the present invention.

FIG. 19 is perspective drawing illustrating the differences between the three-dimensional heaped load profile of FIG. 15 and a load profile produced using a S.A.E. J 1363 (Jan. 1985) 2:1 heap rating standard and a  
5 load profile produced using a 2:1 straight heap rating.

FIG. 20 is a comparison diagram illustrating the differences between the three-dimensional modeled material heap load profile of FIG. 15 as carried in a dump body and a straight 2:1 heap load profile and a S.A.E. 2:1 heap  
10 load profile as carried in the same dump body.

FIG. 21 is a side view of an off-highway truck carrying a load in an exemplary field operating environment.

FIG. 22 is an end view of an off-highway truck carrying a load in an exemplary field operating  
15 environment.

While the invention will be described and disclosed in connection with certain preferred embodiments and procedures, it is not intended to limit the invention to those specific embodiments. Rather it is intended to  
20 cover all such alternative embodiments and modifications as fall within the spirit and scope of the invention.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

Referring now more particularly to the drawings there is shown in FIGS. 1-17 an illustrative sequence of process steps for designing a dump body 10 for an heavy-duty off-highway truck 12 in accordance with the teachings of the present invention. The truck 12 includes a chassis 14 to  
25 which the dump body 10 is attached for pivotal movement about an axis between a lowered position for receiving and transporting a load of material and a raised position for dumping a load of material. As shown in FIG. 17, the dump body 10 is generally constructed of steel panels which  
30 define the shape of the dump body and beams which form the  
35

structural framework for the dump body. The dump body comprises, in this case, sidewalls 16, a front wall or front slope 18, a floor 20 and a canopy 22 integrally connected to the top end of the front slope 18 and  
5 extending over the cab 24 of the truck 12. The truck chassis 14 is supported by a plurality of tires 26.

In the illustrated embodiment, the truck 12 is generally symmetrical about its longitudinal axis. Accordingly, as will be appreciated, many of the elements  
10 identified in the side views of FIGS. 1-7 have complementary elements arranged on the opposite side of the truck 12. As will be appreciated, reference to plural elements where only one is shown indicate that a complementary element is disposed on the side of the truck  
15 12 not shown (e.g., sidewalls 16).

In accordance with an important aspect of the present invention, the dump body 10 is designed so that the volumetric capacity of the dump body matches the truck hauling capacity and that loads in the dump body have a  
20 center of gravity that best matches the intended load center of gravity/corresponding load distribution contemplated by the design of the truck chassis 14. More specifically, the dump body 10 is shaped and dimensioned to accommodate the correct volumetric load as well as to  
25 maintain a load distribution that results in the center of gravity of the load being proximate a predetermined location, in this case, the preferred position for the load center of gravity based on the truck manufacturer's designed chassis loading/weight distribution. Unlike  
30 previous dump body design methods, the dump body design of the present invention is not based on an assumed theoretical or universal load profile/load material heap. Instead, the present invention utilizes a load profile that is based on a detailed analysis of the actual  
35 material characteristics and loading conditions present in

specific field haulage environments thereby taking into account factors such as the cohesiveness of the material to be hauled and the size, shape and gradation of the pieces of material.

5       For example, U.S. Patent No. 5,887,914 issued to LeRoy G. Hagenbuch on March 30, 1999 discloses a dump body design process which can be used to produce a dump body that is capable of hauling both overburden and coal. This design process assumes a theoretical 2:1 heap for  
10 overburden and a theoretical 3:1 heap for coal. It has been found that these theoretical load profile assumptions do not always provide an accurate body design of the actual haulage operating conditions which are encountered at specific job sites. Such theoretical body load  
15 profiles, are used without any consideration of the actual material, loading and hauling conditions that exist at actual locations of use. Thus, in many cases the dump body can be improperly sized and designed or matched to the material to be hauled and accordingly to the truck  
20 chassis.

      In order to more accurately take into account actual field conditions, the first step in the design process of the present invention is to collect field data relating to the material characteristics and load configurations  
25 currently being hauled by trucks at the site at which the dump body 10 will be used. In particular, data should be collected with regard to the actual angles of material repose, the size and shape of any plateau formed at the top of the load and loading voids that are formed by the  
30 material when it is loaded and carried in existing dump bodies. The angles of material repose are dependent upon a number of factors including the cohesiveness of the material being hauled and the size, shape and gradation of the material pieces. With respect to analyzing the angles  
35 of repose, load plateau and loading voids of the loaded

material, one method by which this can be accomplished is to photograph (or videotape) from various different angles the loads 72 presently being hauled by one or more existing off-highway trucks 74 at a site (see, e.g., FIGS. 5 21 and 22). More specifically, photographs should be taken of loads 72 carried by several different existing trucks 74 with photographs being taken from the front, back, corners (front and rear) and sides of those trucks. In order to help identify any shifting of the load that 10 may effect load profiles and which may occur during transport, photographs can be taken of the loaded trucks as they are leaving the loading area as well as when they are traveling on the haul roads.

Furthermore, since the method by which material is 15 loaded into the truck 12 can also impact the loaded material profile, it can also be useful to collect data, via photographs or otherwise, regarding truck loading techniques and the equipment used to load the dump bodies. For example, front-end loaders generally have a wide 20 bucket relative to the dump body length and typically load material into the dump body from the side of the truck. Accordingly, when front end-loaders will be used to load the dump body, the length of the dump body can be an important factor. Likewise, cable and hydraulic shovels 25 tend to have narrower buckets and are also used to load material into the body typically from the side of the truck. Since cable shovels typically have a door which swings toward the shovel when dumping (i.e. towards the side of the body), the width of the body may be an 30 important factor when shovels will be used to load the dump body. Additionally, information should be collected giving an accurate material density. The types of information which can be relevant to determining the density of the load material include visual examinations 35 of the load material, the taking of weight samples of

known volumes of the load material and consultations with the end user of the proposed dump body.

In some circumstances, such as in the case of a new mine, it may not be possible or desirable to collect material and loading data from the site at which the dump body 10 will be used. In these situations, data from a similar field haulage environment should be used. As will be appreciated by those skilled in the art, a similar field haulage environment would have conditions that parallel as closely as possible the conditions which are anticipated at the new site. This could include, for example, a nearby site or mine in which the same or similar material is hauled, a site hauling similar materials and using similar hauling equipment and/or a site using similar loading equipment. Once the new mine or site is operational, the design of future dump bodies for that site can be refined as needed and as information is developed about the material and loading conditions at the site. Of course, the material and loading conditions at sites will, in most cases, evolve over time which could necessitate further analysis of these parameters prior to the design of new additional dump bodies for that site.

Once the appropriate load heap pictorial information has been collected, the information is then analyzed to determine what are the actual angles of material repose of the loaded material and the dimensions of the top plateau of the material heap. In one presently preferred embodiment, this is accomplished by blowing up at least select representative photographs of off-highway trucks with loaded material. From these blown up photographs, the size of the plateau of the heap, the angles of material repose and the corner voids of the loaded materials are then measured. In most cases, the angles of material repose that run to the front, rear and sides of the dump body will all be somewhat different namely due to

the natural and imposed angles of repose occurring as a result of the loading process. Accordingly, using the photographs, values should be determined for each of these angles repose. The various values for the front, rear and side angles of repose which are measured from the photographs are compiled and averaged respectively in order to produce a composite front angle of repose, a composite rear angle of repose and a composite side angle of repose which can then be used to create a three-dimensional load profile as described in greater detail below. Of course, as will be appreciated by those skilled in the art, other methods may be used to collect and analyze the data on actual dump body field haulage conditions including, for example, actual hands-on measurements of the relevant angles of repose and corner voids.

Using the values of the empty and loaded weights of the truck 12 provided by the off-highway truck manufacturer, the ideal position along the chassis 14 for the load center of gravity is then determined. As illustrated in FIG. 1, the correct load center of gravity on the chassis 14 (represented by arrow 28 in the drawings) is located using conventional moment diagrams.

To begin designing the body 10, as shown in FIG. 2, a line 30 is established to represent the plane of the dump body floor. Generally, the angle of the floor line 30 is established to provide an incline with respect to the horizontal plane as illustrated in FIG. 3 and is established at a set minimum distance above the chassis 14 at the front of the body and a set minimum distance above the chassis and/or tires at the rear of the body. A proposed line 32 for the front slope of the dump body is also established, as shown in FIG. 3, at a set minimum distance back from the chassis deck/engine compartment at the bottom end of the front slope and at a set minimum



distance back from the chassis cab 24 at the upper portion of the front slope. To minimize the vertical height of the center of gravity of the load, it is preferable to set the initial front slope line 32 as far forward and the  
 5 initial floor line 30 as low as possible while still maintaining the appropriate clearances for the truck cab 24 and chassis 14. As shown in FIG. 4, the initial proposed inside body width of the body 10 is then set based on 90-115% of the overall rear axle tire width or as  
 10 set by the truck chassis manufacturer.

As shown in FIGS. 5 and 6, using the angles of material repose (i.e. front, rear and sides) data obtained from the analysis of the actual field haulage conditions, an approximate heap profile 33 of the  
 15 material to be hauled is then generated utilizing the individual average values for the front, rear and sides angles of material repose 34, 36, 40 (e.g., 24°, 30° and 32° respectively in the illustrated embodiment) taken from the field data. Additionally, as shown in FIG. 5,  
 20 an initial dump body side height (referenced as line 37) is established at the point where the front angle of material repose 34 contacts the front slope line 32. The placement of the center of gravity of the approximate heap profile 33 along the truck chassis 14 is then  
 25 determined and compared with the optimal location along the chassis for the load center of gravity (arrow 28).

The angle of the floor line 30, the lengths of the front slope line and floor line and the line defining the height of the sidewalls are adjusted as indicated by the  
 30 arrows in FIG. 7 so that through an iterative process, the center of gravity of the load can be located as close as possible to the correct truck chassis 14 load center of gravity while maintaining the desired body volume. In adjusting the various parameters, it is preferable to keep  
 35 the center of gravity of the load as low as possible in

order to provide the best truck chassis stability. Accordingly, in the iterative process used to locate the center of gravity of the load in the desired position, it is generally preferable to focus on adjusting the height of the sidewalls and the length of the floor, versus rotating the rear of the floor. For example, either lowering the sidewalls and lengthening the floor to move the center of gravity rearward relative to the chassis 14 or raising the sidewalls and shortening the floor to move the center of gravity forward relative to the chassis 14. Using an iterative process, the width of the body 10 may also be adjusted with the slopes and lengths (within given parameters) of the floor and front slope in order to minimize the overall load height profile. While overall loading height of the dump body influences the size of the loading equipment that is required, lower overall dump body loading heights improve truck stability and lessen the need for larger loading equipment. Lower overall dump body loading heights also necessarily allow the load material to be dropped into the dump body from a lower point, thereby minimizing the impact force of the load material on the dump body. Obviously, the wider the body 10, the lower the center of gravity. As a practical limit, however, the body 10 generally should not be significantly wider than the overall width of the rear axle measured from the outer edges of the rear tires or as preset by the truck chassis manufacturer.

Next, based upon this approximate load profile 33 (e.g., shown in FIG. 6) and the data on the actual field haulage conditions, a three-dimensional model 38 (e.g. shown in FIGS. 8-15) of the load heap is developed which incorporates corner voids and the actual side angles of material repose 40 (e.g.,  $32^\circ$ ), front and rear angles of material repose 34, 36 (e.g.  $24^\circ$  and  $30^\circ$ ) and a top of heaped load plateau 48 as measured from the actual field

collected data. The process/steps used to develop the three-dimensional modeled heaped material load profile 38 are generally shown in FIGS. 8-15 with the outline of the truck body 10 shown in triple solid lines and the outline of the three-dimensional model 38 shown in broken lines. To account for corner voids (corners of the body where no hauled material is located) in the three-dimensional modeled load profile 38, the transition areas between the sides and the front and the rear of the load are modeled based on a gradual incremental blending of the side angle of material repose 40 to the front and rear angles of repose 34, 36 (which angles of repose may or may not be different. After the corner voids are so modeled, the modeled voids are then compared to the information collected in the field and the corner voids may then be adjusted so as to as closely as possible match the modeled corner voids with the actual field corner voids. As will be appreciated, the steps described in FIGS. 5-7 are used only to expedite the design process and are not necessary to the present invention. In particular, one can move directly to using the three-dimensional model 38 of the load heap (with the corner voids) and eliminate the steps shown in FIGS. 5-7.

To this end, in one preferred embodiment, the transition areas between the front 42 and the sides 44, and the rear 46 and the sides 44 of the three-dimensional load model 38 are divided into a number of equal segments as shown in FIG. 9. In the illustrated embodiment, the creation of the corner voids (e.g., FIG. 15) through the transitional blending of the angles of repose is only shown with respect to one of the front corners and one of the rear corners of the load. Of course, it will be appreciated that the same methodology described herein can be used to model the voids in the other corners of the load. In the illustrated embodiment, the boundaries

of the transition areas between the sides 44 and the front 42 and rear 46 portions of the three-dimensional load model 38 form  $90^\circ$  angles defined by the flat top or plateau 48 (FIG. 8 and 9), as defined by actual field  
 5 operating data, of the load model 38, with each of the transition areas being divided into nine equal  $10^\circ$  segments. Planes 50 (FIG. 9) are established in each of these segments which extend at a respective angle of repose that allows, if required, an incremental change in  
 10 the angle of repose through the corners from the sides 44 to the front 42 and rear 46 of the three-dimensional load model 38. In particular, the difference between the side and rear angles of repose, in this case  $2^\circ$ , and the side and front angles of repose, in this case  $8^\circ$  is divided  
 15 into nine equal incremental segments as shown in FIG. 9.

Each of these planes 50 is then extended using standard geometric principles until it intersects a portion of the dump body 10 such as the floor, side walls, front slope or canopy as shown in FIGS. 10a-c and  
 20 11. Specifically, as shown in FIGS. 10a-c, end points are established for each of these planes by using the values of the angles of material repose for each of the segments and the horizontal distance for each respective segment from the appropriate corner of the load plateau 48 to the perimeter of the dump body 10 to calculate the  
 25 horizontal and vertical positions for the end points of the planes. Each plane 50 is then extended to its respective end points (FIG. 11). Next, any portion of the planes 50 which extends beyond the boundaries of the dump body 10 (referenced as 62, 64 and 66 in FIGS. 12-13)  
 30 is then "cut-off" at the point at which it intersects the dump body to define the corner edges of the three-dimensional load model 38 as shown in FIGS. 12 and 13. The completed three-dimensional load heap profile 38 is

shown in FIG. 14 and arranged in the dump body 10 in FIG. 15.

Once the three-dimensional modeling of the material heap is completed, including the modeling of the corner voids along with a subsequent comparison with the field gathered information, the center of gravity of the resulting three-dimensional load model 38 is then determined. This center of gravity is then compared to the center of gravity location (arrow 28) contemplated by the chassis design as shown in FIG. 16. If the center of gravity of the three-dimensional load model 38 is in close proximity to the center of gravity location contemplated by the chassis design then the design of the dump body 10 is complete. It is generally desirable to have the load center of gravity as close as is practical to the desired chassis location. While the distance will vary depending upon the relative length of the wheelbase of the truck, in one preferred embodiment the center of gravity will be considered sufficiently close to the desired location if it is within less than one inch (plus or minus) from the desired location. Due to the inherent design characteristics of off-highway trucks (in an empty condition an inordinate amount of the net weight of the truck is carried on the front axle), in most circumstances, the center of gravity of the three-dimensional load profile should not be allowed to be positioned forward of the center of gravity location contemplated by the chassis design.

In the event that the center of gravity of the three-dimensional load model 38 is not close enough to the desired location, in an iterative process a new three-dimensional profile of the heaped load is generated based on the data collected from the field loading/haulage environment. Through adjustment of the parameters of the dump body (e.g., the dump body floor

angle, floor length and side height), the center of gravity of this new three-dimensional heaped load profile is moved through the iterative process until it is in close proximity to the desired location. These steps  
5 being repeated in an iterative fashion as necessary until the center of gravity of the three-dimensional load model is adjusted to be approximately coincident with the anticipated center of gravity contemplated by the design of the truck chassis 14.

10 The final design of the dump body 10 is shown in FIG. 17. In accordance with the present invention, the body 10 is custom modeled/designed based on specific field material, loading and hauling conditions and thus when the body is used in the field it will carry the desired  
15 volumetric hauling capacity and the center of gravity of the load will be in closer proximity to the desired center of gravity location than bodies designed using theoretical heap load profiles (see, e.g., FIG. 20).

FIGS. 18a-b are a flow diagram which illustrates the  
20 individual steps in the design process of the present invention which are described herein and shown in the drawings of FIGS. 1-17. For ease of reference, the steps in the flow diagram of FIGS. 18a-b are numbered to correspond with the numbering of the steps in FIGS. 1-17.  
25 As will be appreciated by those skilled in the art, steps 6 and 7 shown in FIGS. 18a-b can be considered optional in the design process.

As will be appreciated, the use of actual angles of repose gathered from data taken from the actual field  
30 haulage conditions in which the dump body 10 will be employed can have a significant impact on the model of the load and thus ultimately on the design of the dump body. For example, as shown in FIG. 19, in the illustrated example of a load having actual 32° side, 24°  
35 front and 30° rear angles of repose, the three-

dimensional load modeling process of the present invention results in a significant amount of material being removed from the front and rear and through part of the corners of the three dimensional load model 38 as compared to a standard 2:1 heap model 54 and a S.A.E. 2:1 heap model 52 as defined by S.A.E. Standard No. J 1263 (Jan. 1985) (with the profiled three-dimensional model created using the present invention shown in broken lines and the S.A.E. 2:1 heaped model and standard 2:1 heaped model shown in solid lines). In this case, the three-dimensional load modeling process of the present invention also results in a significant amount of load material being added to the sides in the three-dimensional load model 38 as compared to the S.A.E. 2:1 heap and the standard 2:1 heap.

An example of how these differences in the load model can impact the location of the center of gravity of the load as it is carried in a dump body and the rated capacity or yardage of the dump body is shown in FIG. 20 (which is a side view of the load models shown in FIG. 19). More particularly, in FIG. 20, the location of the center of gravity and capacity of the three dimensional load model 38 as carried in a dump body is compared to the center of gravity and rated capacity of load models using the S.A.E. 2:1 heap standard model 52 or the 2:1 heap model 54 in the same dump body. As can be seen, the use of the S.A.E. 2:1 standard heap model 52 and the 2:1 heap model 54 results in the center of gravity being offset from the ideal location and in an overstatement of the truck body capacity. Of course, FIGS. 19 and 20 provide just one illustrative example of the differences between the three dimensional modeled heaped load profiles which result from using the process of the present invention as compared to heaped load models created using theoretical load profiles. Since the load

modeling process of the present invention is dependent upon angle of repose data collected from the actual field haulage environment, the differences which result from using the load modeling process of the present invention  
5 as compared to the theoretical load profiling will vary on a case-by-case basis.

In view of the foregoing, it will be appreciated that, unlike the theoretical load profiling currently being done, the body and design process of the present  
10 invention takes into account the field material, loading and hauling conditions in which the dump body will be used and provides a method by which this information can be used in a meaningful manner in designing the dump body. Thus, a much more accurately designed dump body is  
15 produced resulting in improved body capacity and corresponding load retention, and proper placement of the load on the truck chassis and tires.

All of the references cited herein, including patents, patent applications, and publications, are hereby  
20 incorporated in their entirety by reference.

While this invention has been described with an emphasis upon preferred embodiments, it will be obvious to those of ordinary skill in the art that variations of the preferred embodiments may be used and that it is intended  
25 that the invention may be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications encompassed within the spirit and scope of the invention as defined by the following claims.



## WHAT IS CLAIMED IS:

1. A body of a vehicle for hauling material, the body made by the following process:

- (a) determining the desired load distribution of weight on a chassis of the haulage vehicle;
- (b) determining the desired volumetric capacity for the body;
- (c) establishing a line for a floor, a line for a front wall of the body and an inside body width;
- (d) developing a three dimensional model of the hauled material carried in the body using data collected from an anticipated point of use with the three dimensional model of the hauled material having a distribution of weight on the chassis;
- (e) adjusting a set of design parameters of the body until the three dimensional model distribution of weight on the chassis is substantially similar to the desired distribution of weight on the chassis and the volumetric capacity of the body is substantially similar to the desired volumetric capacity; and
- (f) producing the body in accordance with the set of design parameters.

2. The invention according to claim 1 wherein the set of design parameters of the body includes a position of the body floor and a position of body sidewalls.

3. The invention according to claim 2 wherein the position of the body floor includes a length of the floor.

4. The invention according to claim 2 wherein the position of the body sidewalls includes a height of the sidewalls.

5. The invention according to claim 4 wherein the position of the body sidewalls further includes a distance between the respective sidewalls.

5 6. The invention according to claim 2 wherein the set of design parameters of the body further includes a position of the body front wall.

7. The invention according to claim 4 further  
10 including the step of adjusting the length of the body floor and the height of the body sidewalls to provide the lowest practical vertical location for the center of gravity of the three dimensional model of the hauled material.

15

8. The invention according to claim 1 wherein the data collected from the anticipated point of use includes angles of material repose of an actual load carried in an existing vehicle body.

20

9. The invention according to claim 8 wherein the angles of material repose include a front angle of material repose, a rear angle of material repose and side angles of the material repose.

25

10. The invention according to claim 9 wherein the field collected data further includes a representation of corner voids present in an actual load carried in an existing vehicle body.

30

11. The invention according to claim 10 wherein the field collected data includes angles of material repose of and representations of corner voids present in actual loads carried in a plurality of existing vehicle bodies.

35

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12. The invention according to claim 1 wherein the field collected data further includes a density of the load material.

5        13. The invention according to claim 10 wherein the field collected data further includes a method for loading material into an existing vehicle body.

10        14. The invention according to claim 10 wherein the step of developing the three dimensional model of the hauled material includes modeling the corner voids of the hauled material.

15        15. The invention according to claim 14 wherein the corner voids of the hauled material are modeled through a gradual incremental blending of the respective side angles of material repose to the front angle of material repose and a gradual incremental blending of the respective side angles of material repose to the rear  
20        angle of material repose through respective corners of the three-dimensional model of the hauled material.

25        16. The invention according to claim 14 further including the step of comparing the modeled corner voids with the field collected representation of the corner voids and adjusting the modeled corner voids as necessary such that the modeled corner voids substantially match the representation of the corner voids.

30        17. The invention according to claim 15 wherein the incremental blending of the side angles of material repose to the front and rear angles of material repose includes dividing the respective corners of the three-dimensional model into equal segments, establishing a  
35        plane in each of these segments at a respective angle

which allows an incremental change in the angles of material repose through the corners of the three dimensional model and extending the planes until they intersect the perimeter of the body.

5

18. The invention according to claim 1 wherein the step of developing the three dimensional model of the hauled material includes modeling the corner voids of the hauled material.

10

19. The invention according to claim 1 further including the step of adjusting the set of design parameters to provide the lowest practical vertical location for the center of gravity of the three dimensional model of the hauled material.

15

20. The invention according to claim 1 further including the step of adjusting the set of design parameters to allow material to be loaded into the dump body from the lowest practical vertical location.

20



**ABSTRACT OF THE DISCLOSURE**

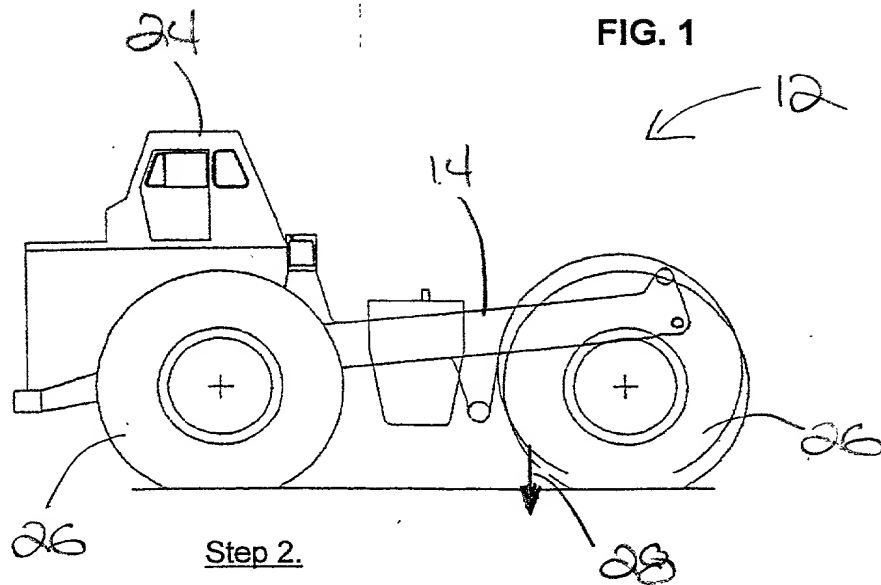
A process for designing dump bodies which more accurately takes into account field loading/haulage conditions is provided. The process includes gathering data from actual field environments including material density, front, rear and side angles of material repose and corner void information. From this data, a three dimensional model of the load is generated. This three dimensional load model is then used to design the truck body in an iterative process until the volume of the truck body and the distribution of weight of the three dimensional load model on the truck chassis is substantially the same as the desired volume and the distribution of weight on the truck chassis.

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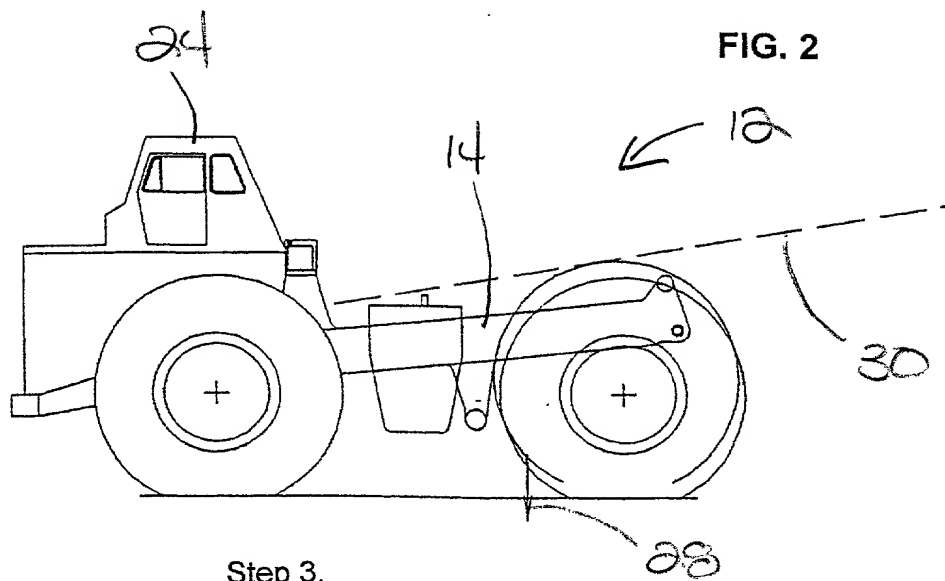
FIG. 10



Step 2.

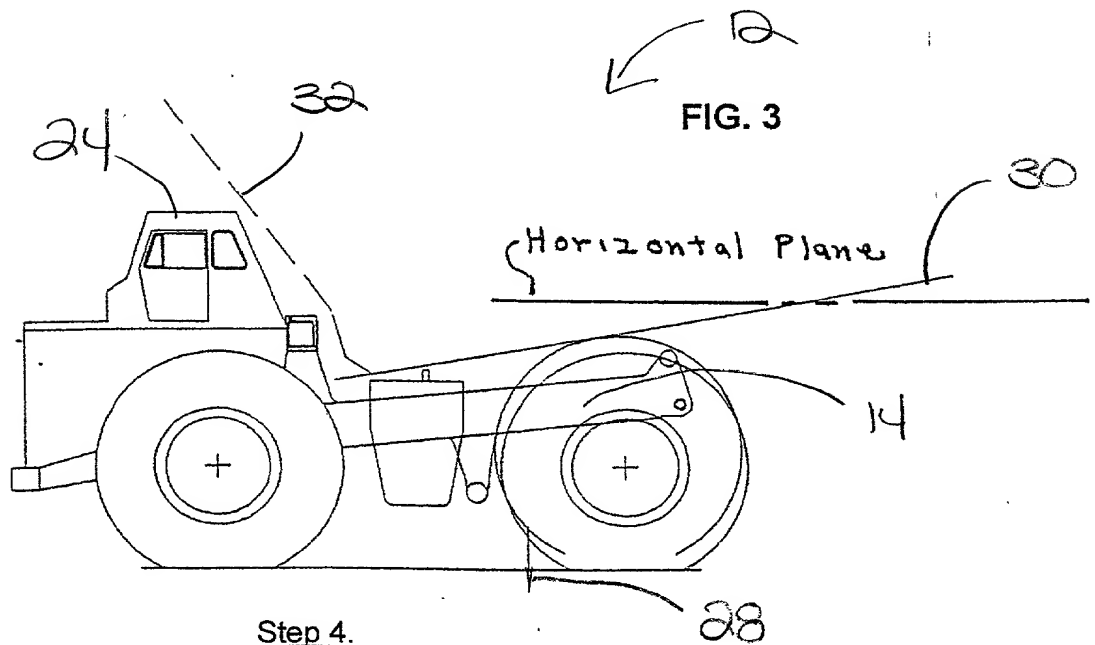
Using truck chassis empty and loaded weights establish "Load" center of gravity.

FIG. 2



Step 3.

Establish proposed body floor line.



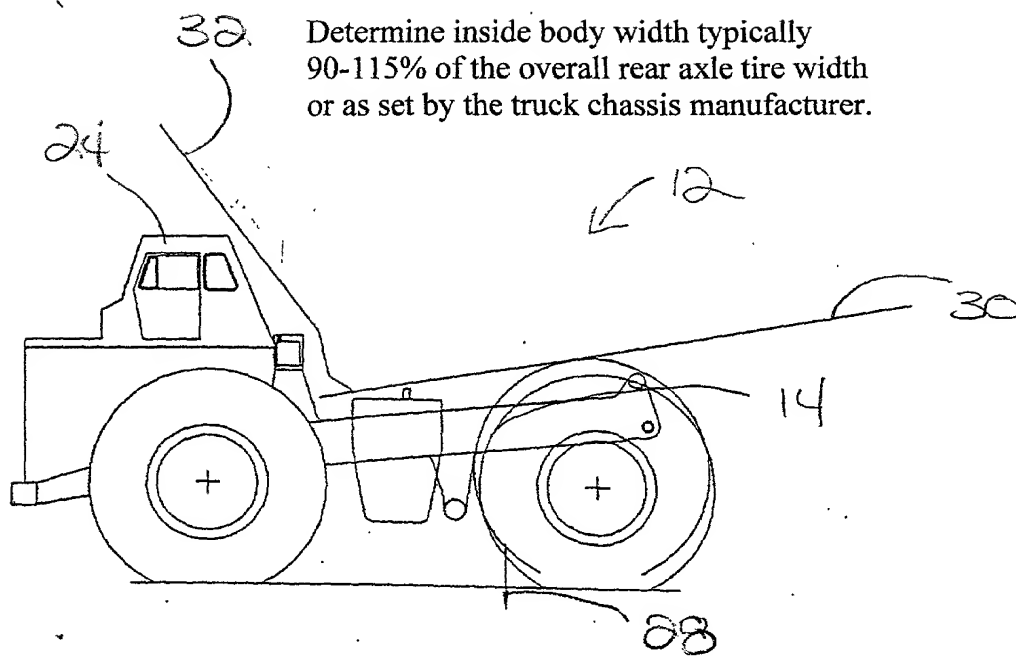
Step 4.

Establish proposed body front slope line.

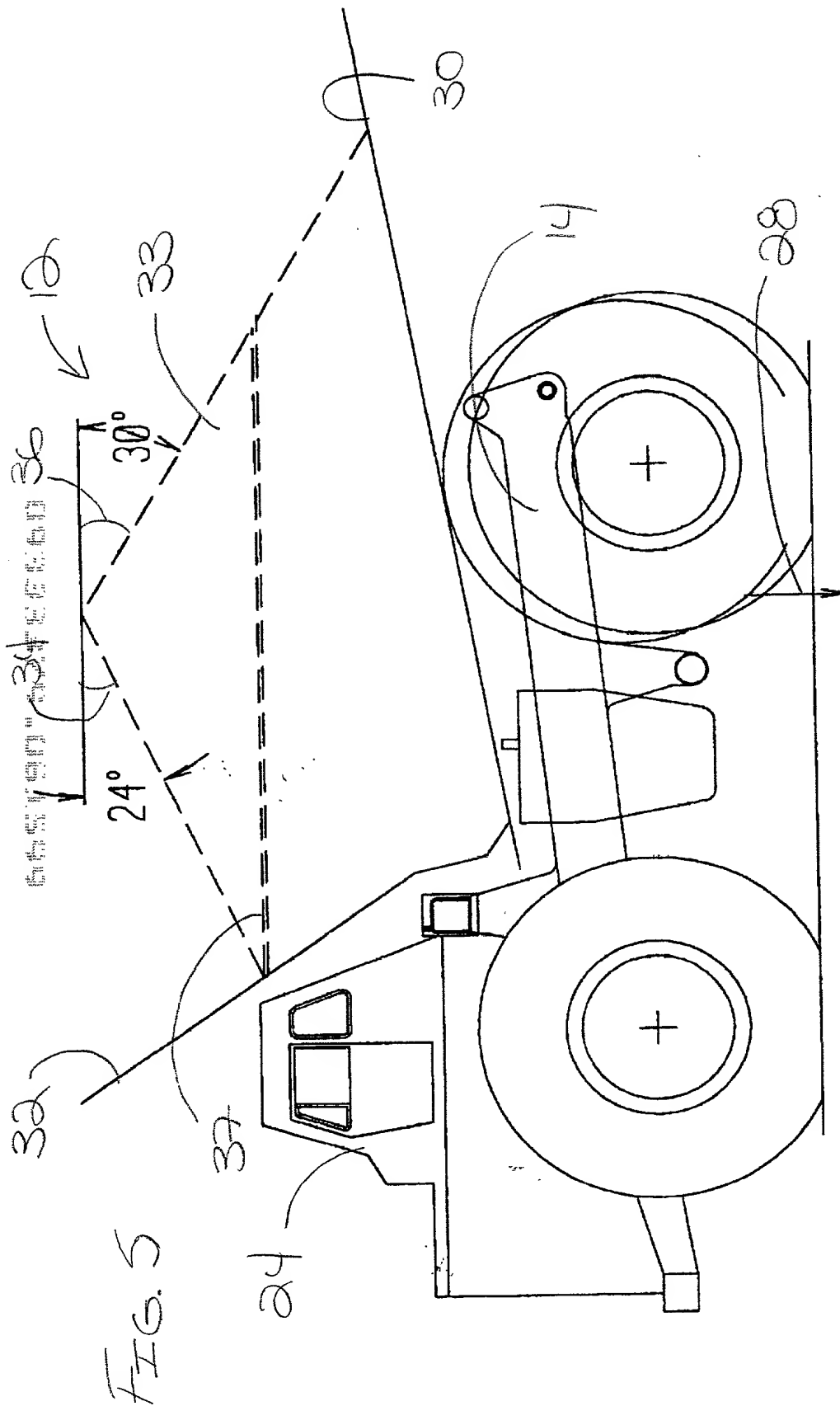
FIG. 4

Step 5.

Determine inside body width typically 90-115% of the overall rear axle tire width or as set by the truck chassis manufacturer.

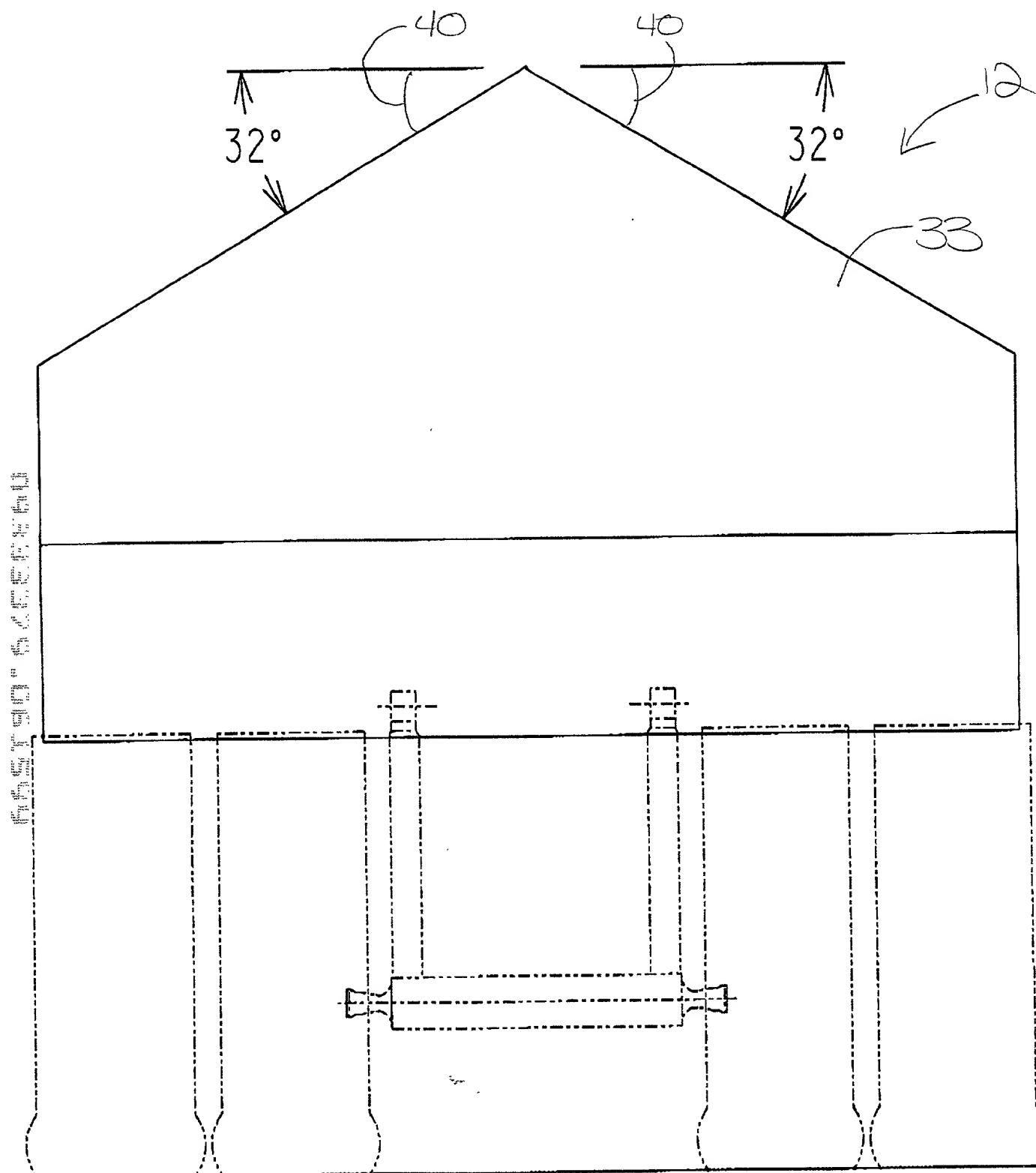






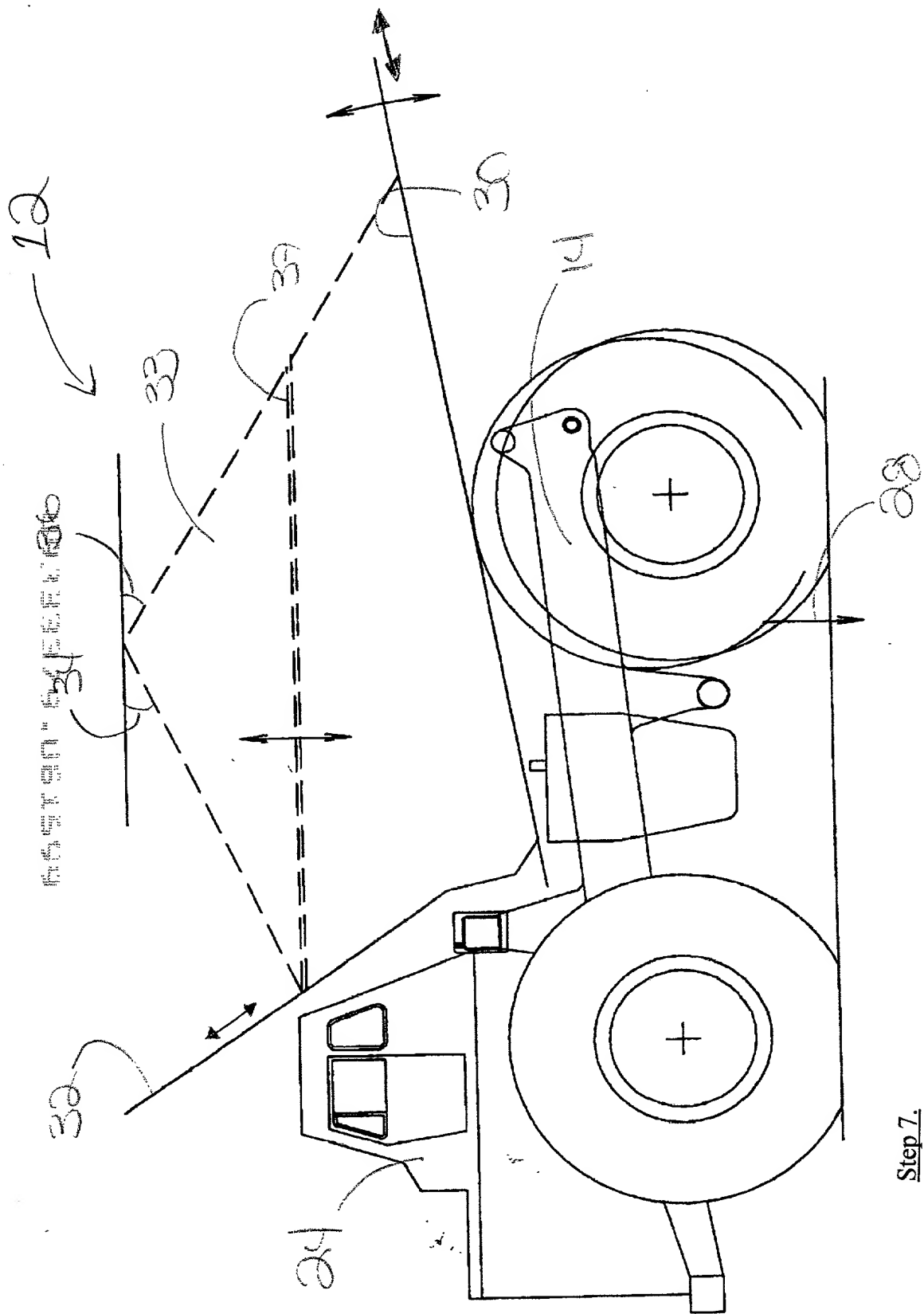
# Step 6.

Using customer specific information, develop an approximate heap profile. Determine the center of gravity of the approximate heap profile and compare it to the correct center of gravity of Step 2.



Step 6.

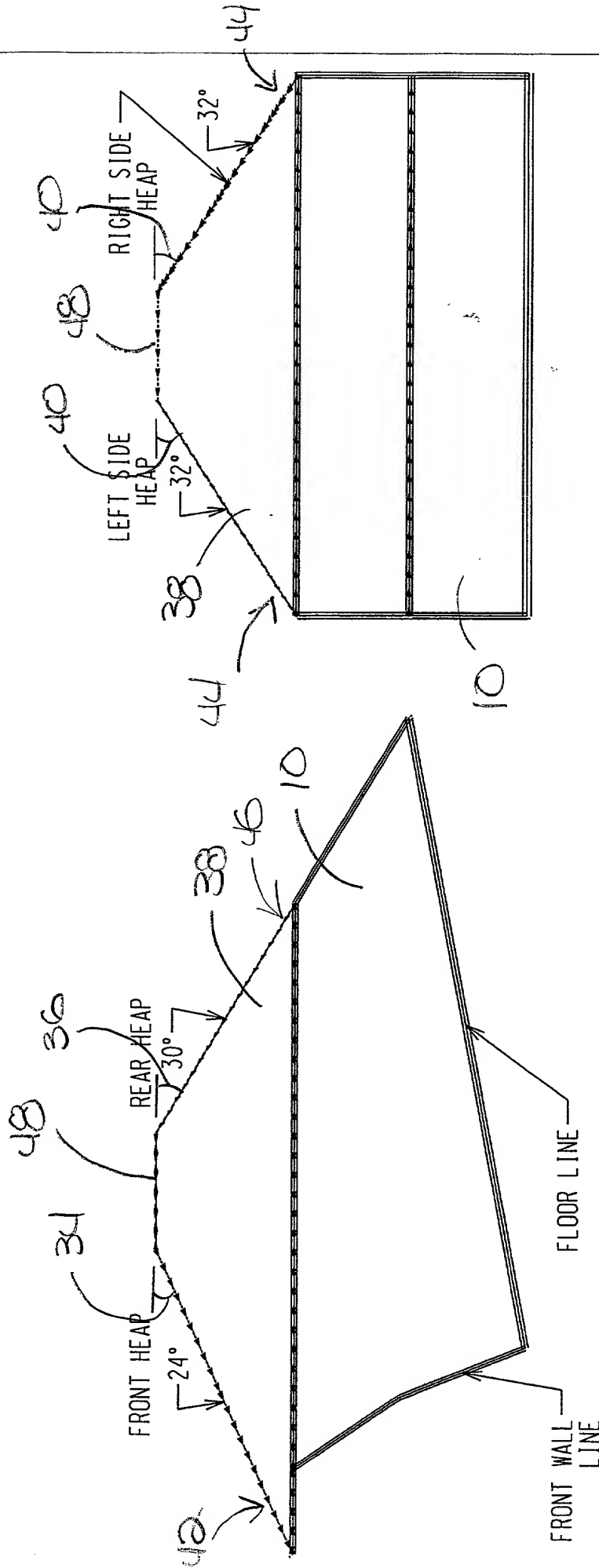
FIG. 6



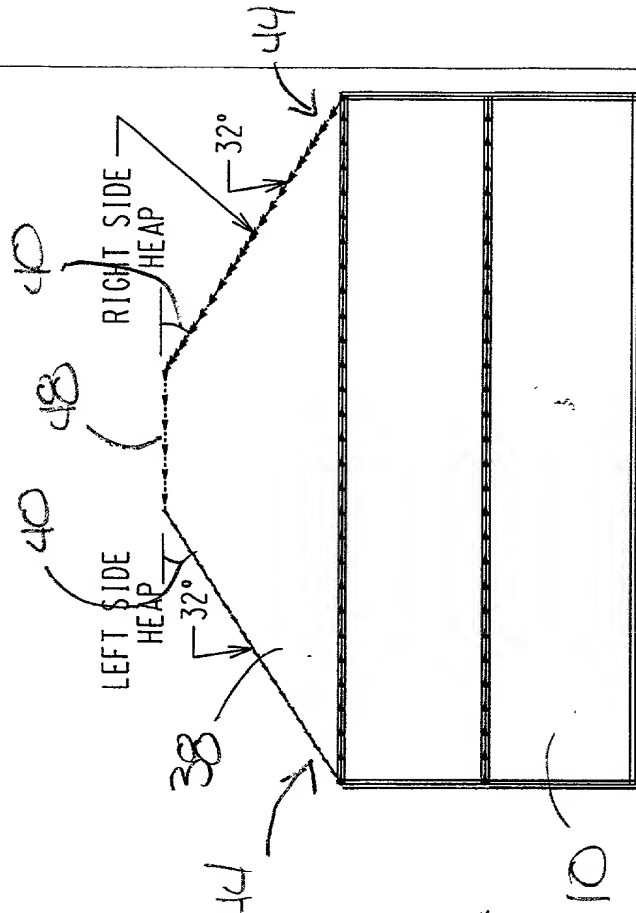
Step 7.

Adjust body floor line, body front slope line and body sidewalls as needed to obtain the correct center of gravity of Step 2.

FIG. 7



177



100

Step 8.

Based on the specific customer information and the resulting load profile, a three dimensional model is developed which incorporates the actual side, front and rear angles of material repose and corner voids.

FRONT

26.7° 25.8° 24.9° 24°

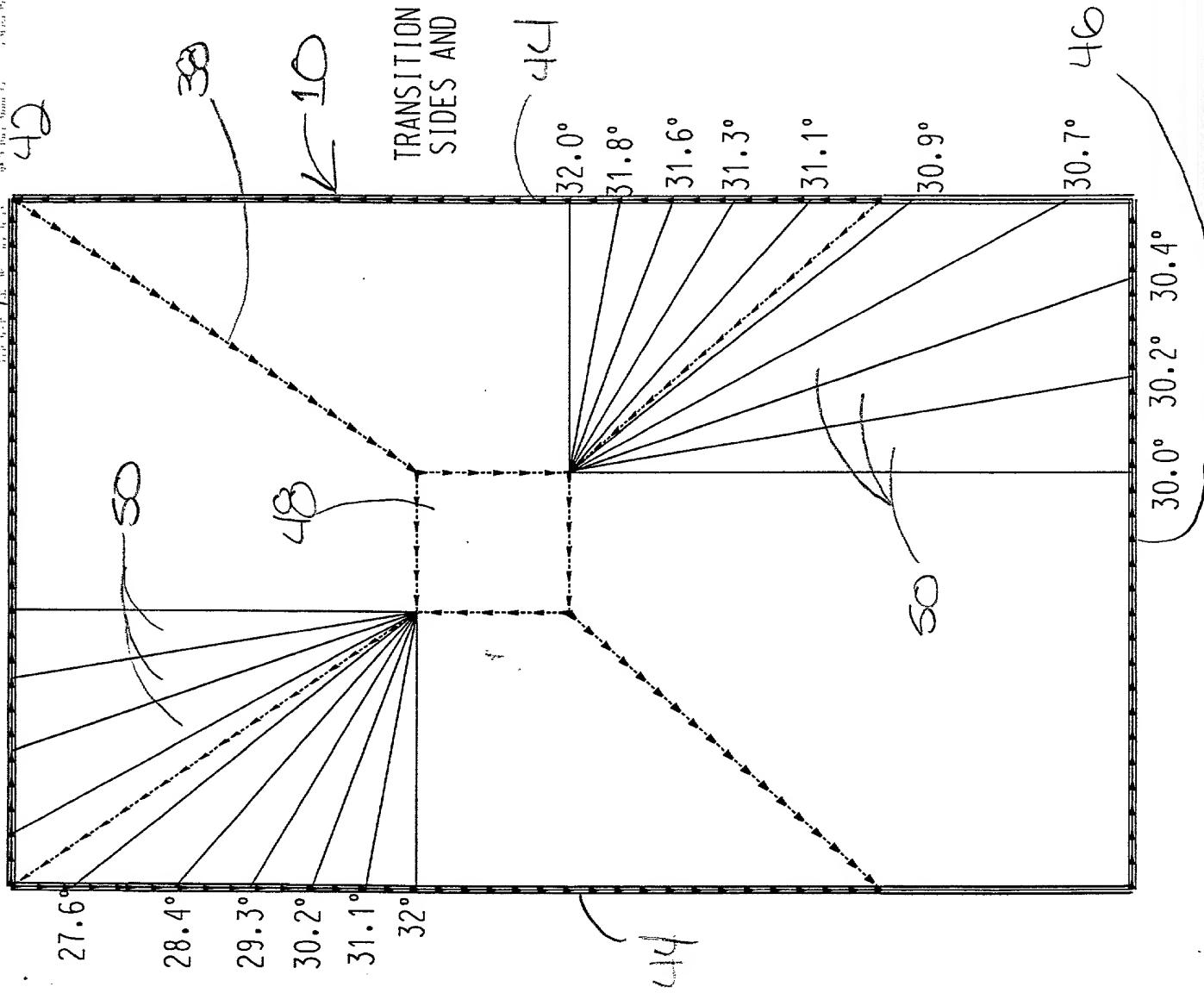


FIG. 2

Step 8, cont.

TRANSITION BETWEEN SIDES AND FRONT AND  
SIDES AND REAR ARE BROKEN INTO EQUAL  
10° SEGMENTS.

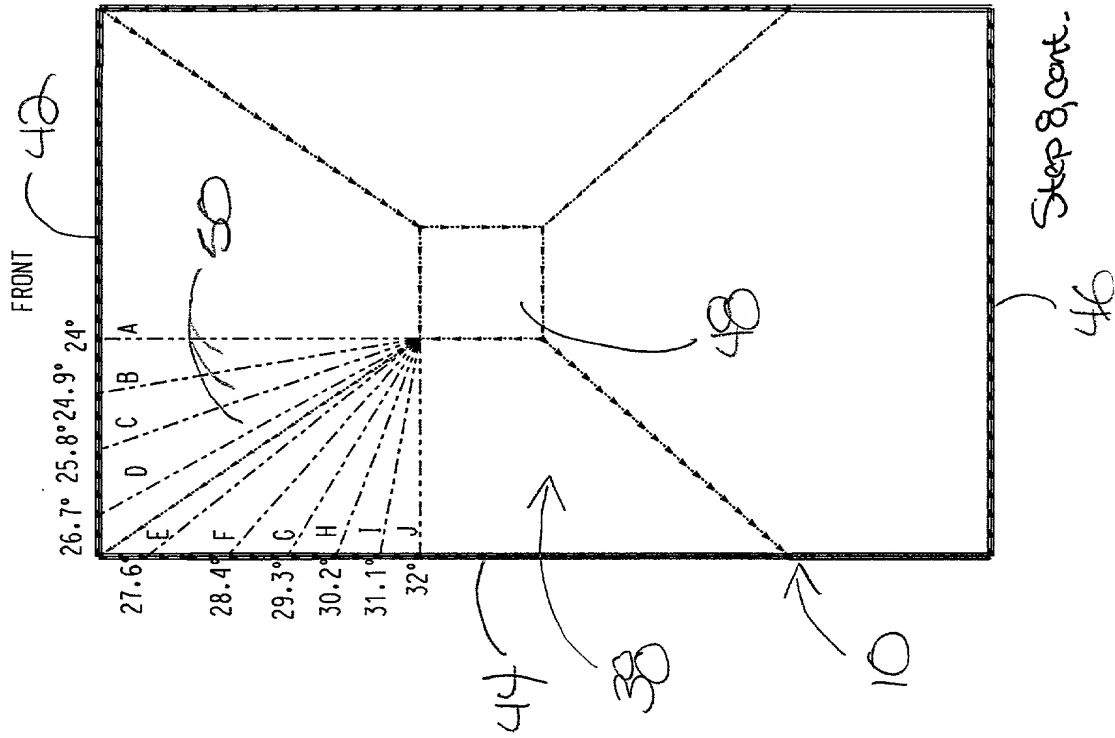


FIG. 10a

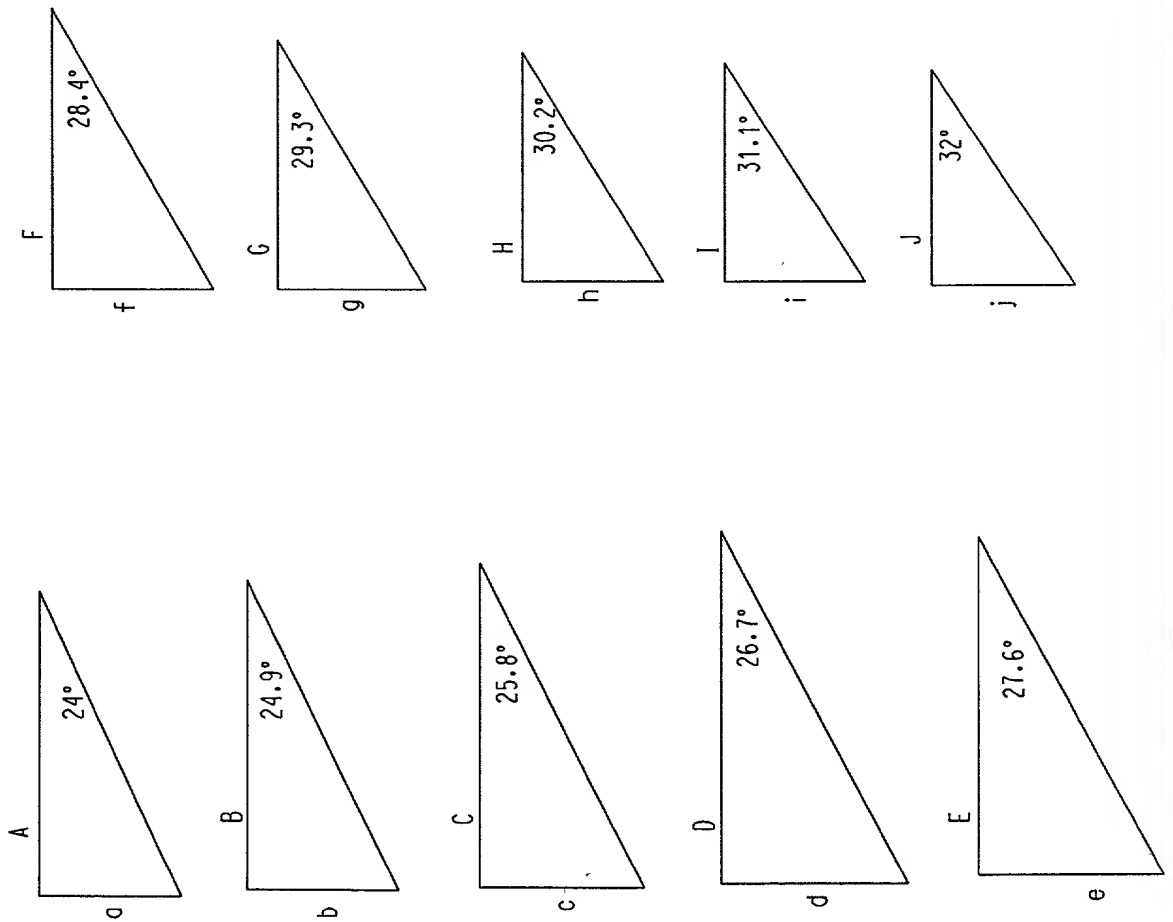
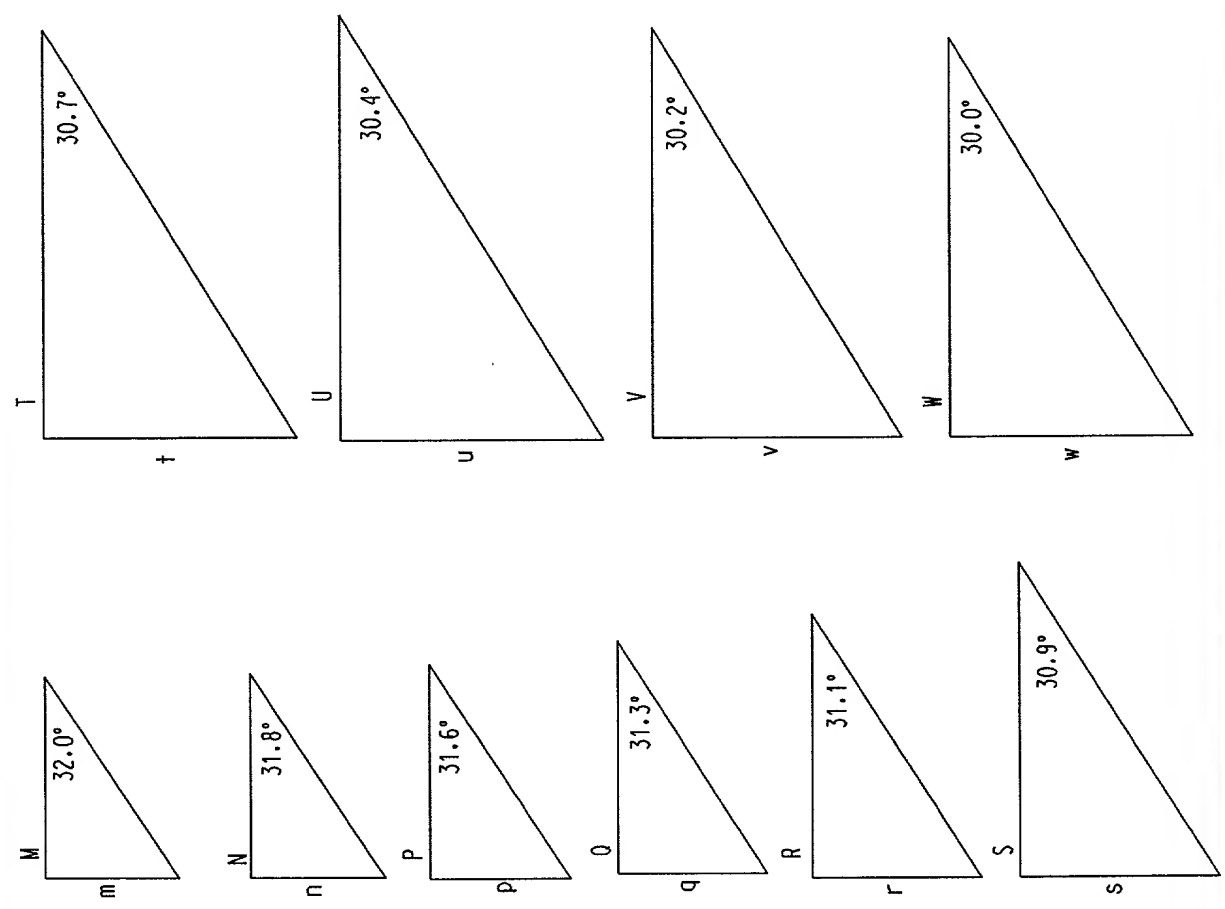
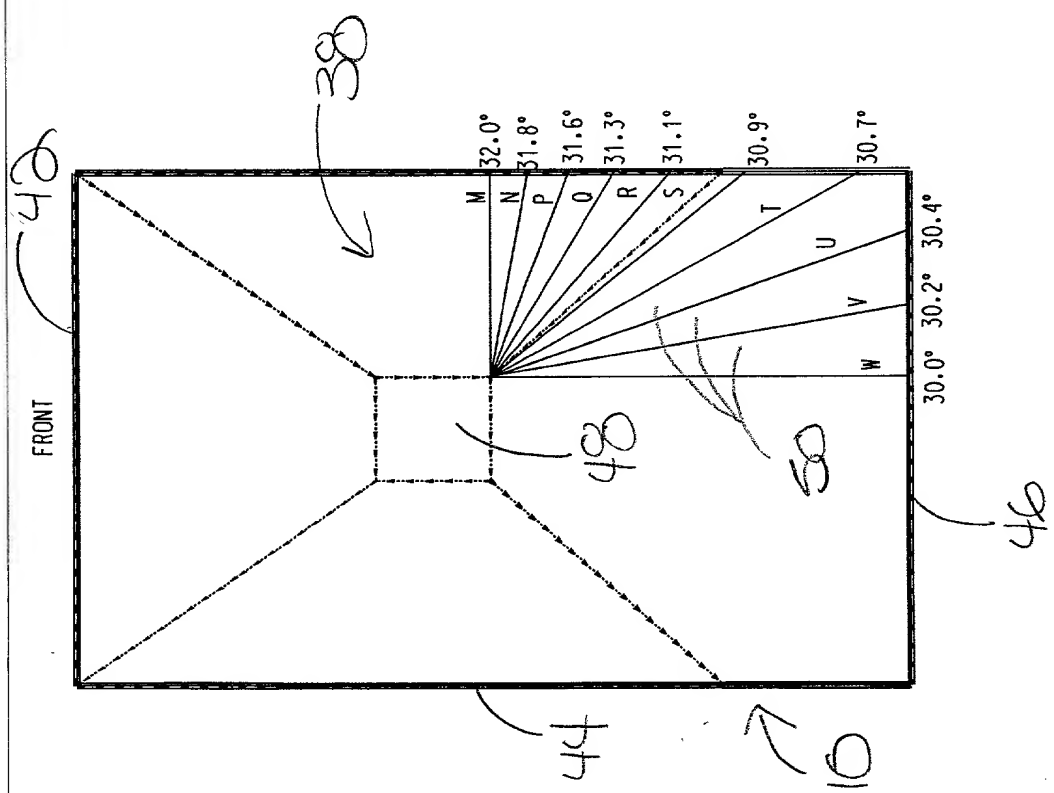


FIG. 10a



Step 8, cont.

FIG. 10b

FIG. 10C

Step 8, cont.

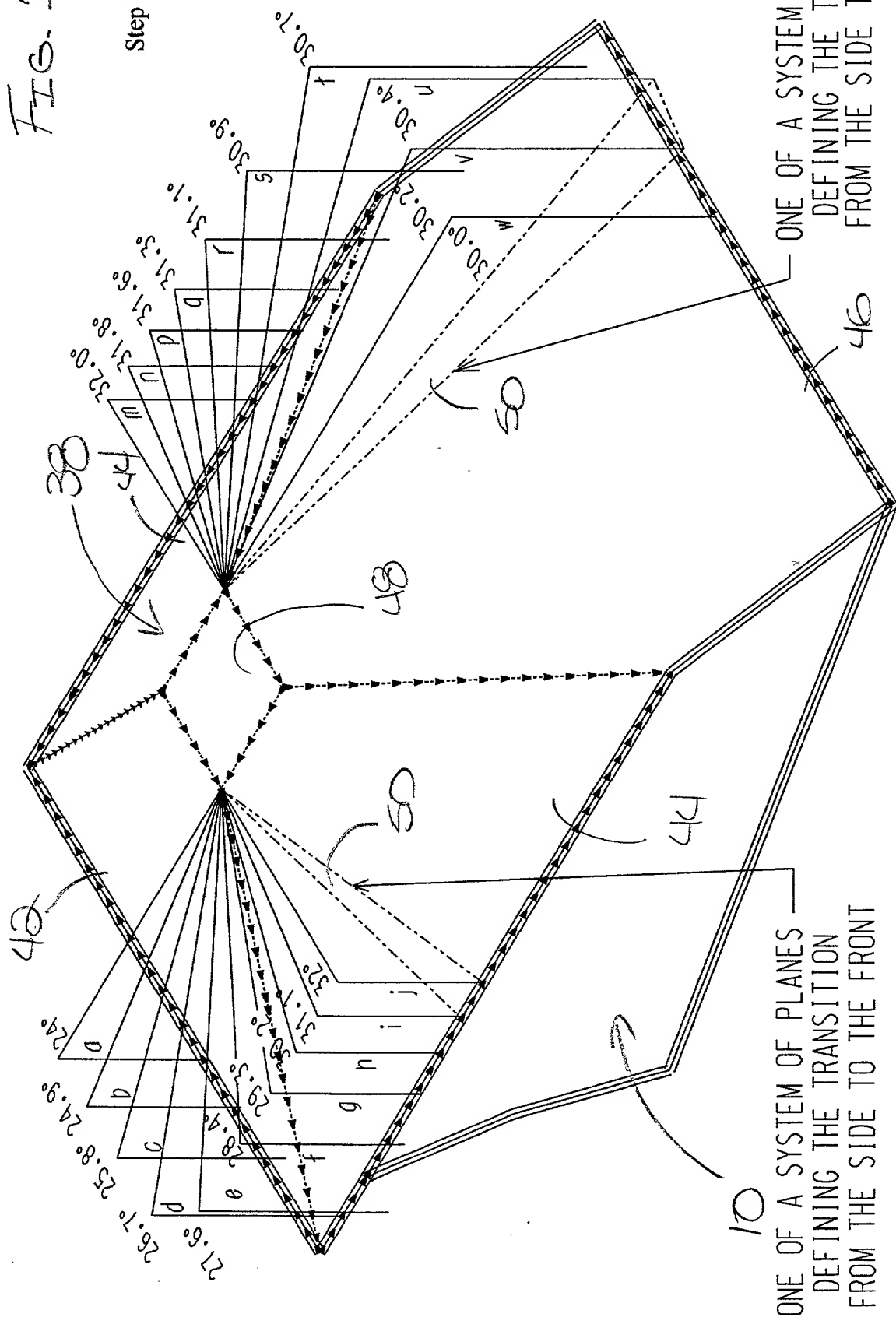








FIG. 13

Step 8, cont.

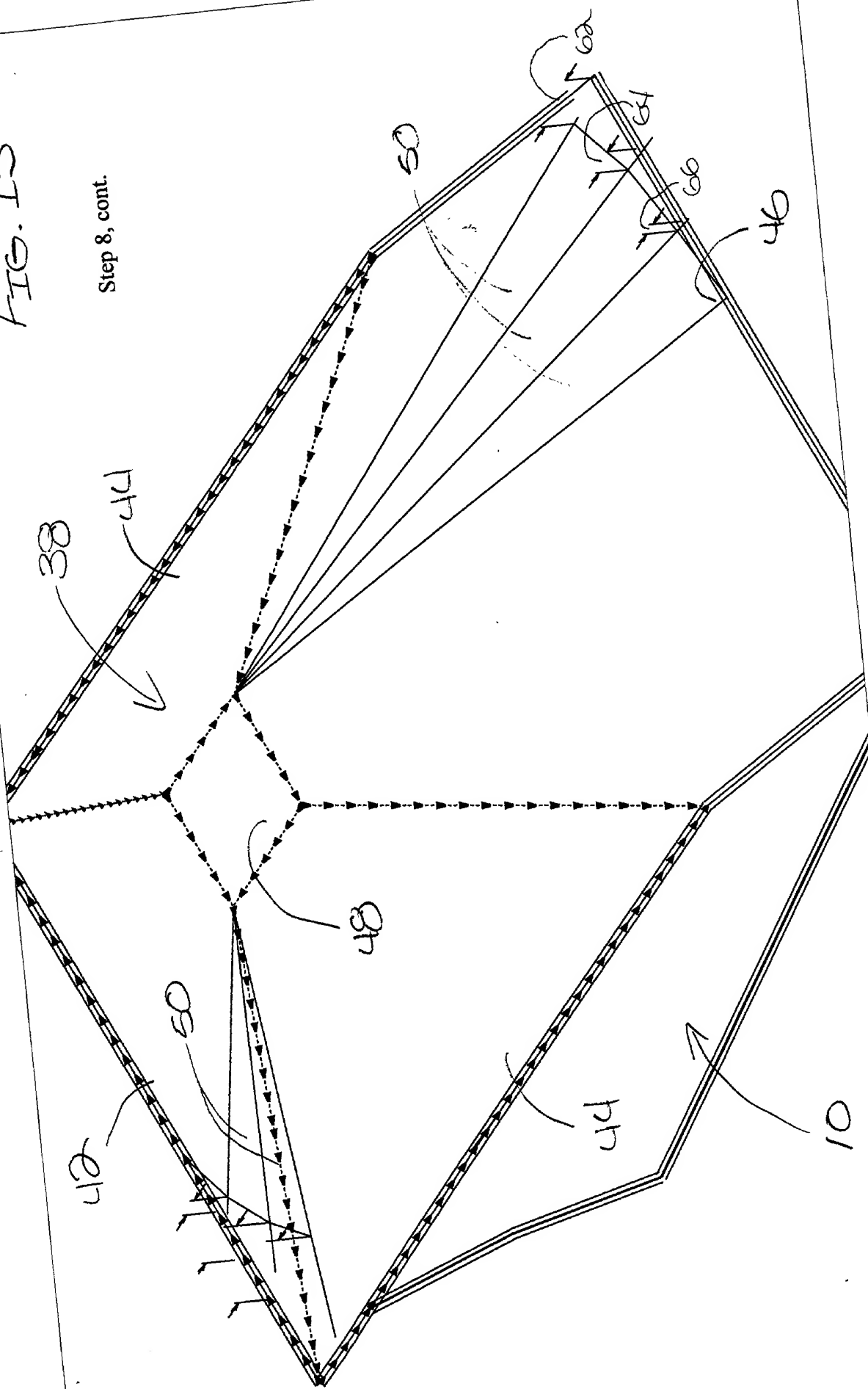


FIG. 14

Step 8, cont.

The diagram illustrates a circular sector divided into multiple segments. The segments are labeled with reference numerals: 38, 40, 42, 44, 46, and 50. The segments are arranged in a radial pattern, with some segments being shaded or cross-hatched. A dashed line is visible near the bottom right, indicating a continuation of the pattern. The drawing is labeled "FIG. 14" and "Step 8, cont.".

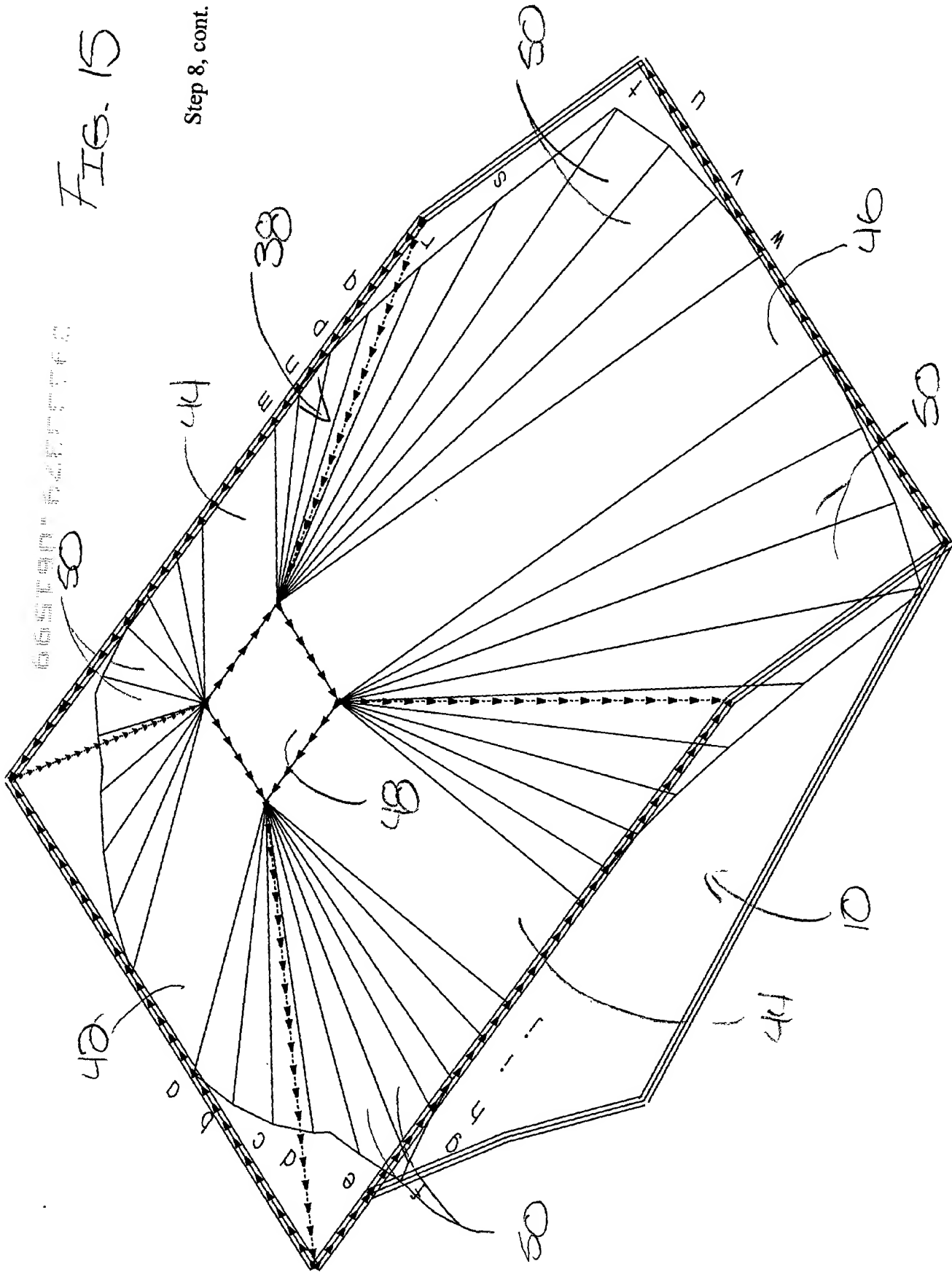
FIG. 14

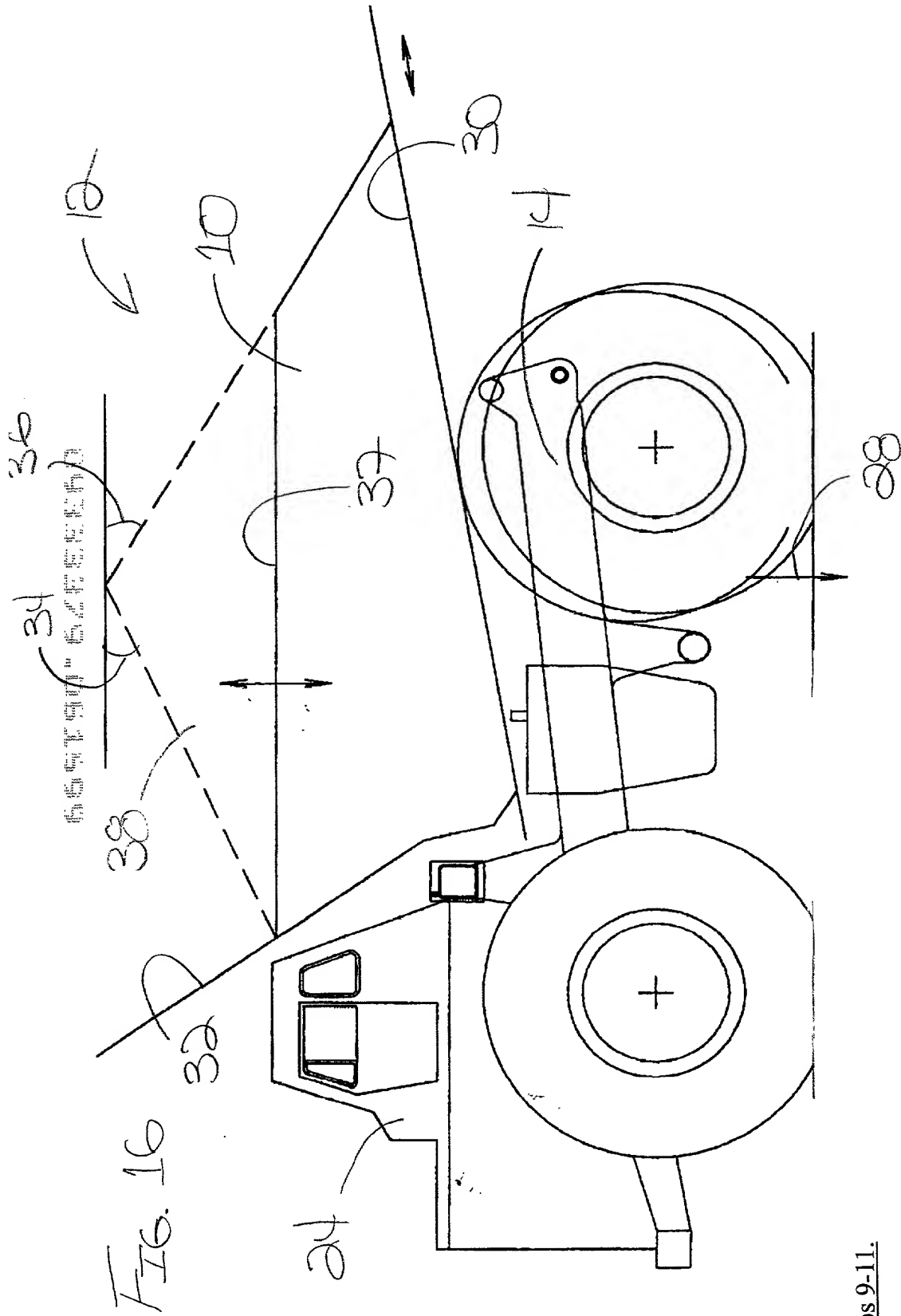
Step 8, cont.

The diagram illustrates a circular sector divided into multiple segments. The segments are labeled with reference numerals: 38, 40, 42, 44, 46, and 50. The drawing shows a series of radial lines and concentric arcs, with some segments shaded or cross-hatched. A dashed line is also visible near the bottom right.

FIG. 15

Step 8, cont.



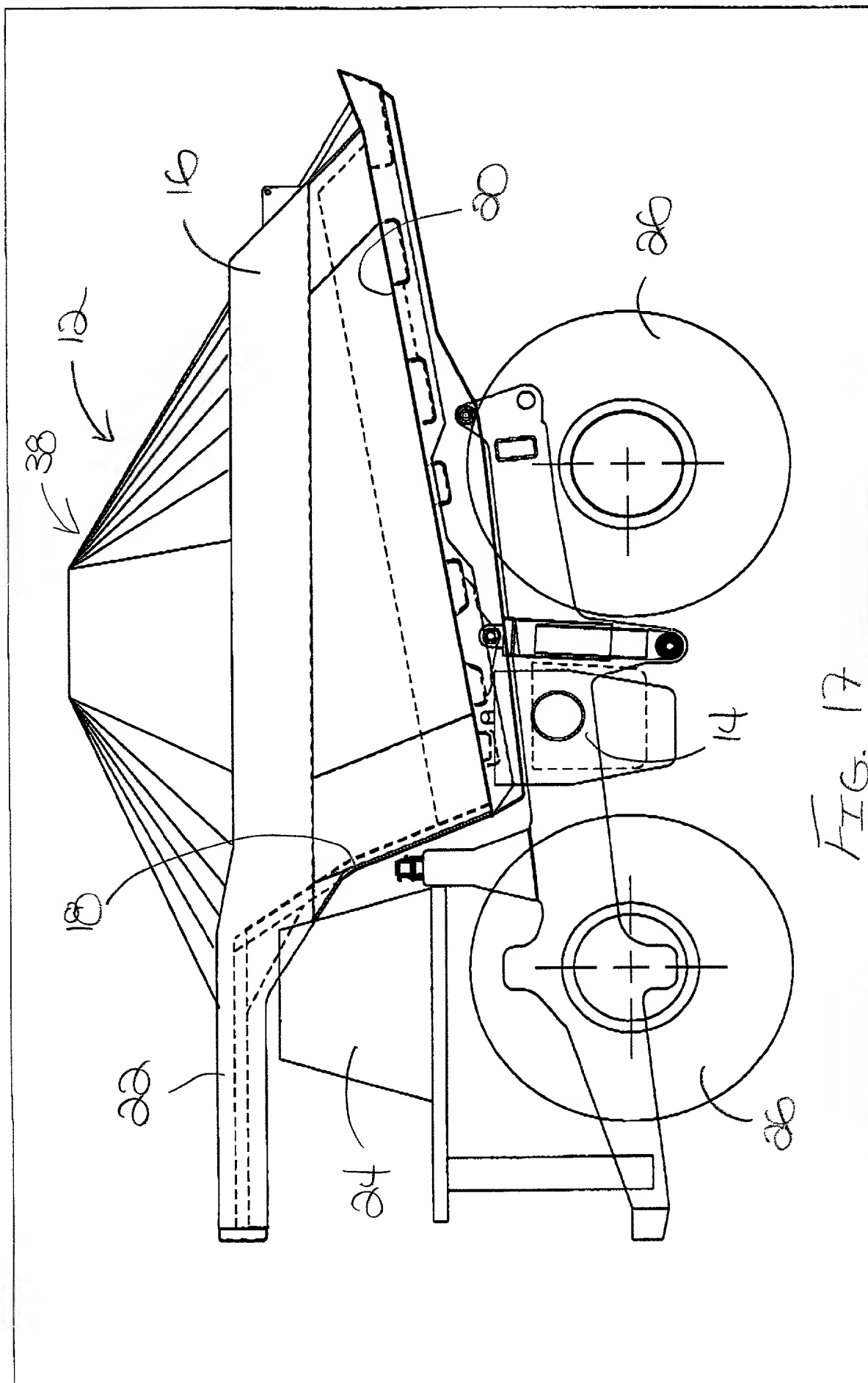


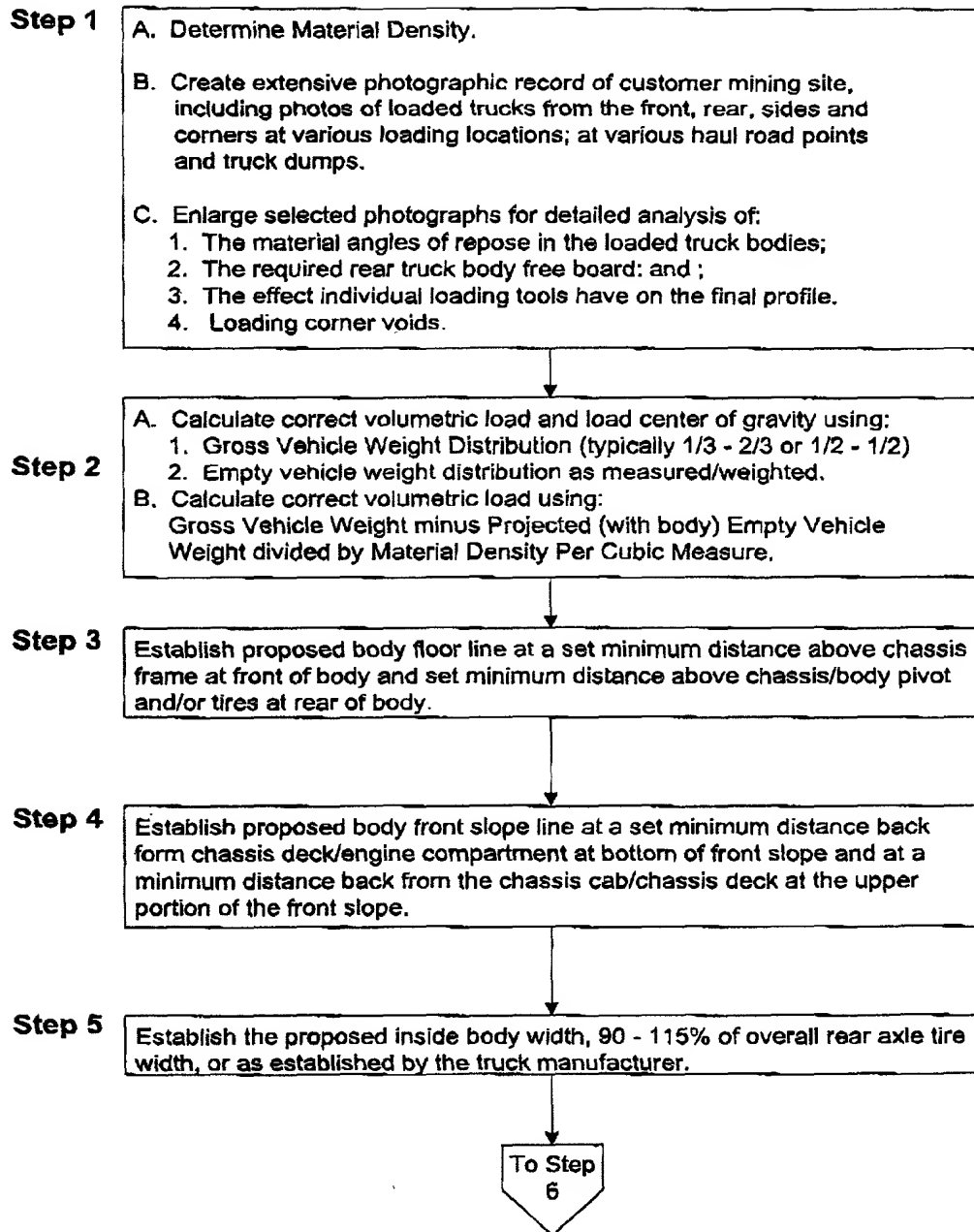
Steps 9-11.

The center of gravity of the three-dimensional load model of Step 8 is determined and then compared to the correct center of gravity of the load as determined in Step 2.

If the center of gravity of the three-dimensional load model is not properly positioned, then a new three dimensional load model is created based on the customer specific data and through adjustment of the design parameters of the dump body in an iterative process so that the load center of gravity of the load model is placed

FIG. 17





**Fig. 18A**



**Fig. 18B**

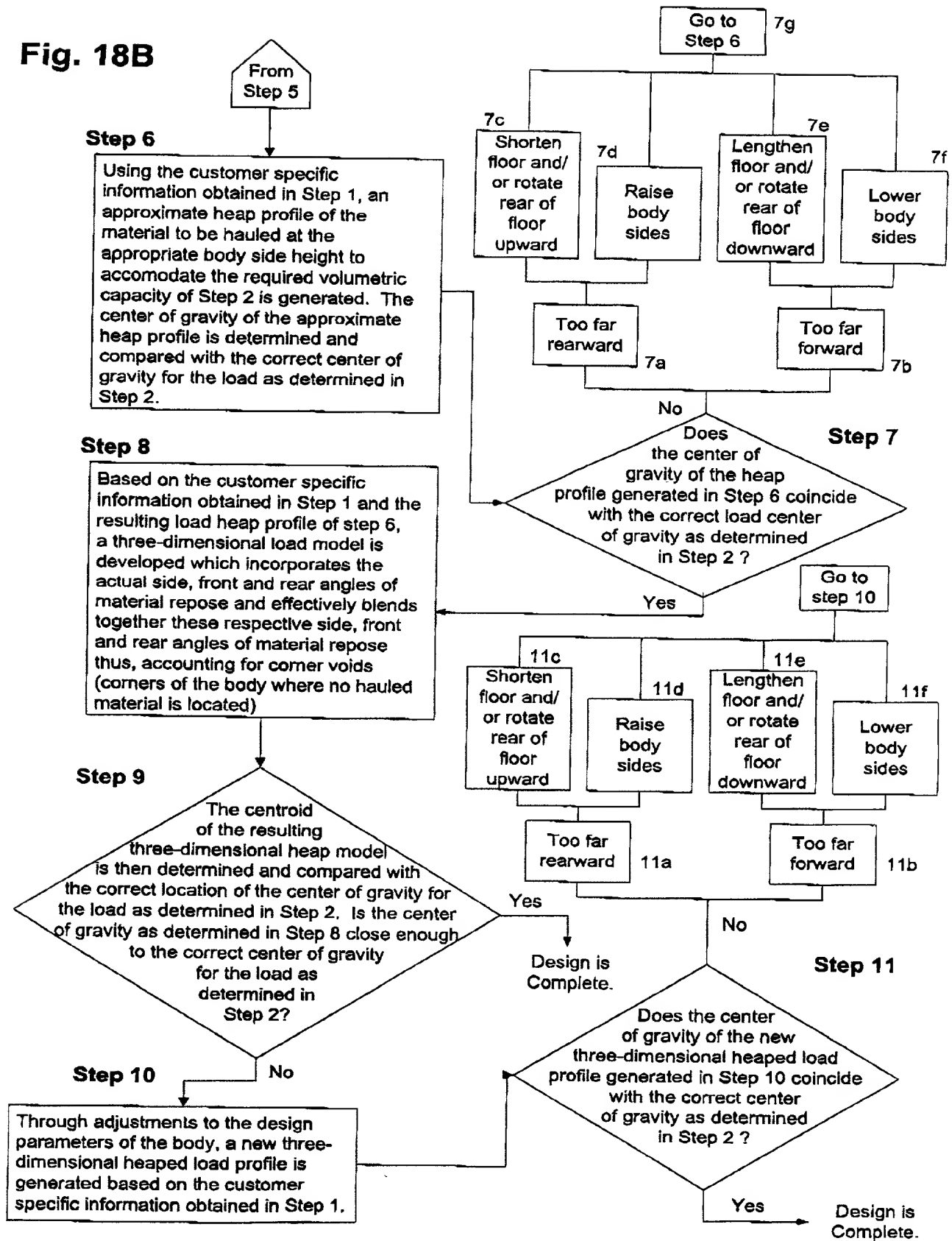
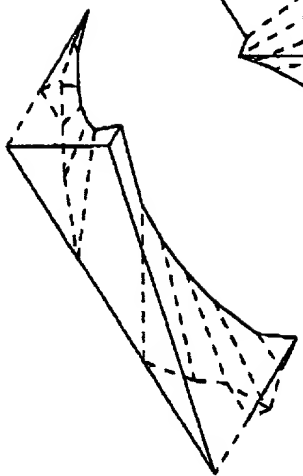
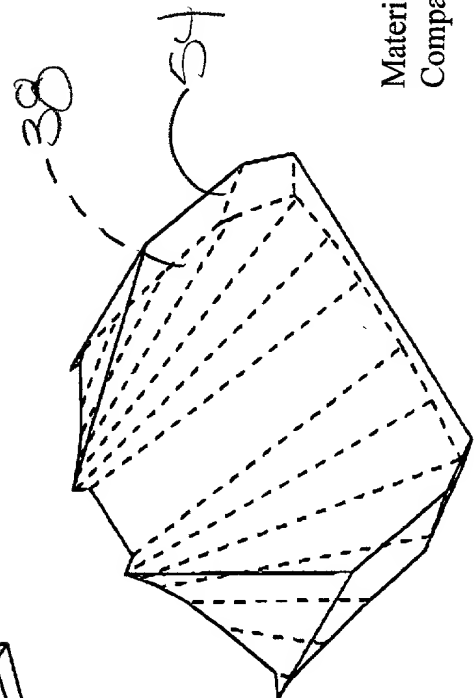


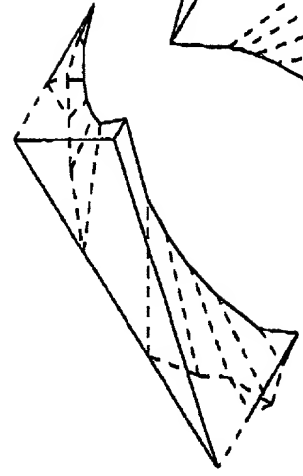
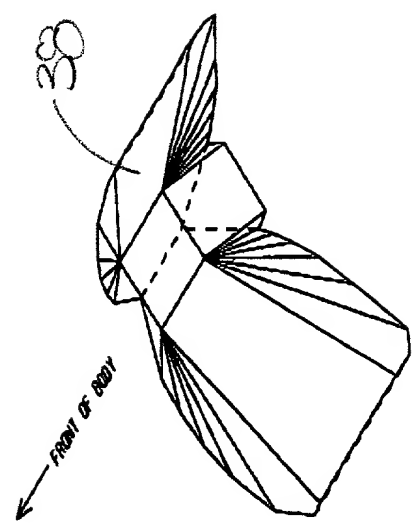
FIG. 19



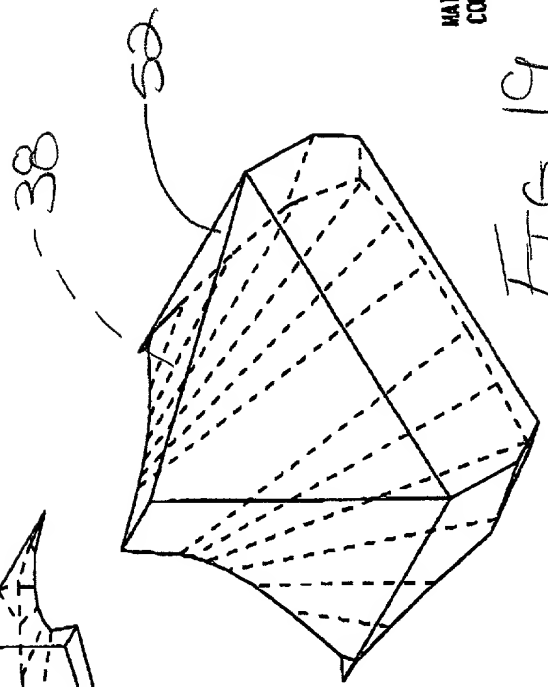
Material Removed By Profiling  
Compared to 2:1 Heap



Material Added By Profiling  
Compared to 2:1 Heap



MATERIAL REMOVED BY PROFILING  
COMPARED TO S.A.E. 2:1 HEAP



MATERIAL ADDED BY PROFILING  
COMPARED TO S.A.E. 2:1 HEAP

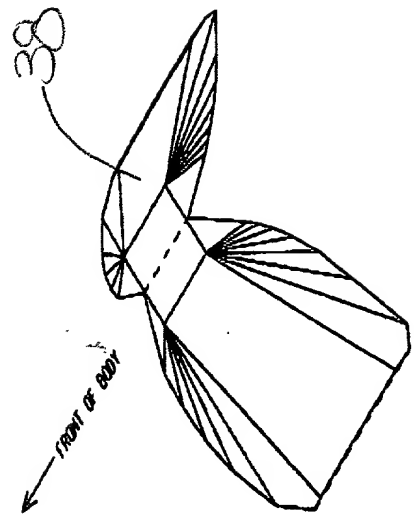
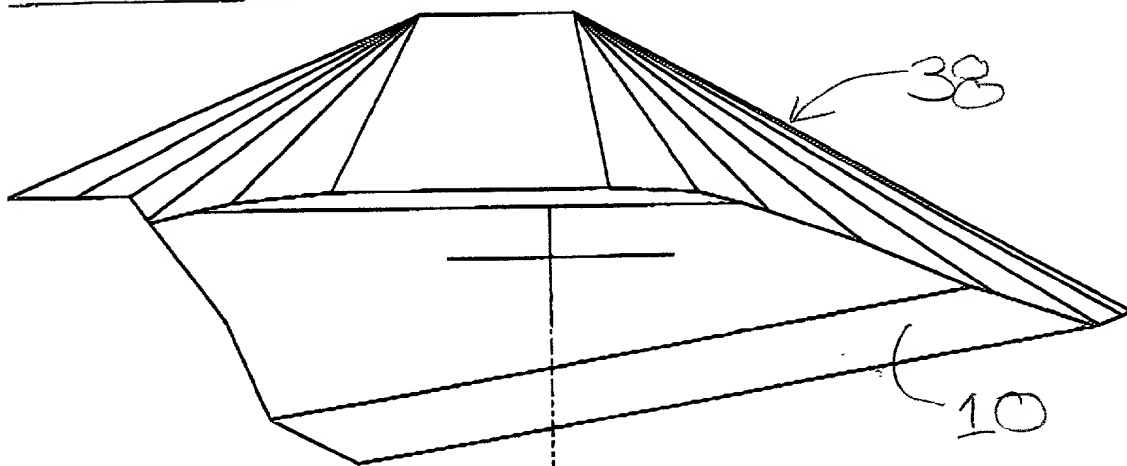
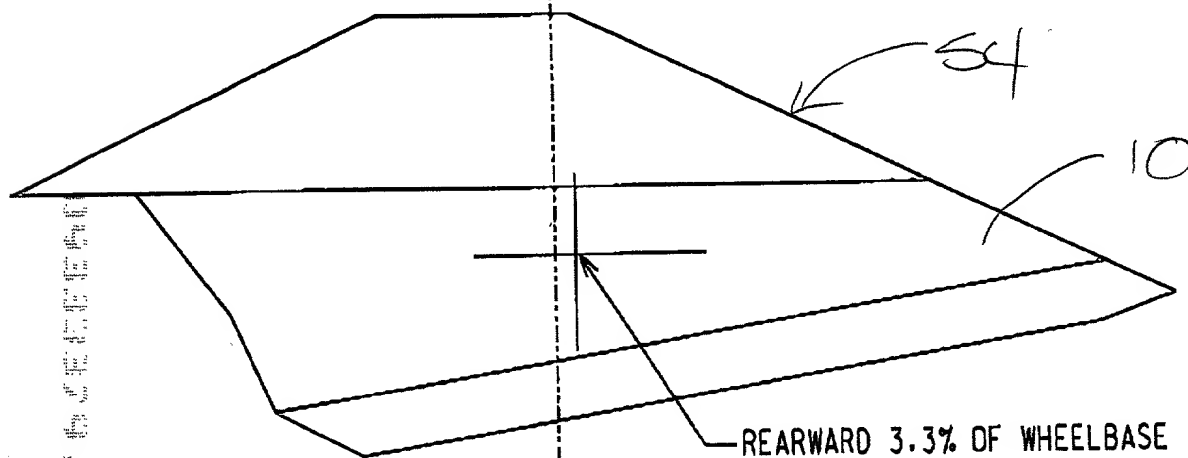


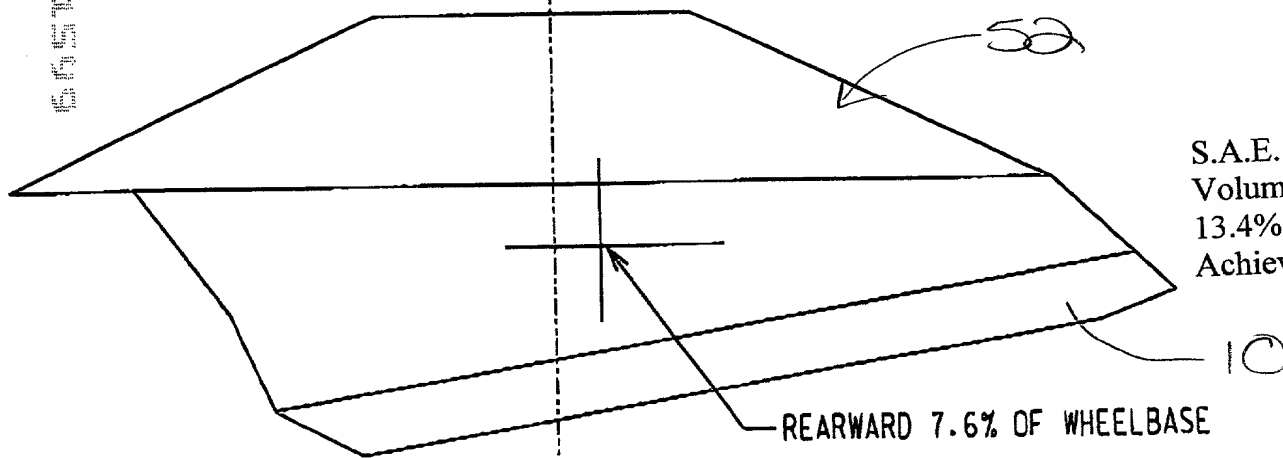
FIG. 19



Three Dimensional  
Load Model Of The  
Present Invention



2:1 Heap  
Volumetric Rating  
5.6% Greater Than  
Achievable



S.A.E. 2:1 Heap  
Volumetric Rating  
13.4% Greater Than  
Achievable

LOCATION OF IDEAL  
HORIZONTAL CENTER  
OF GRAVITY

FIG. 20

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FIG. 21

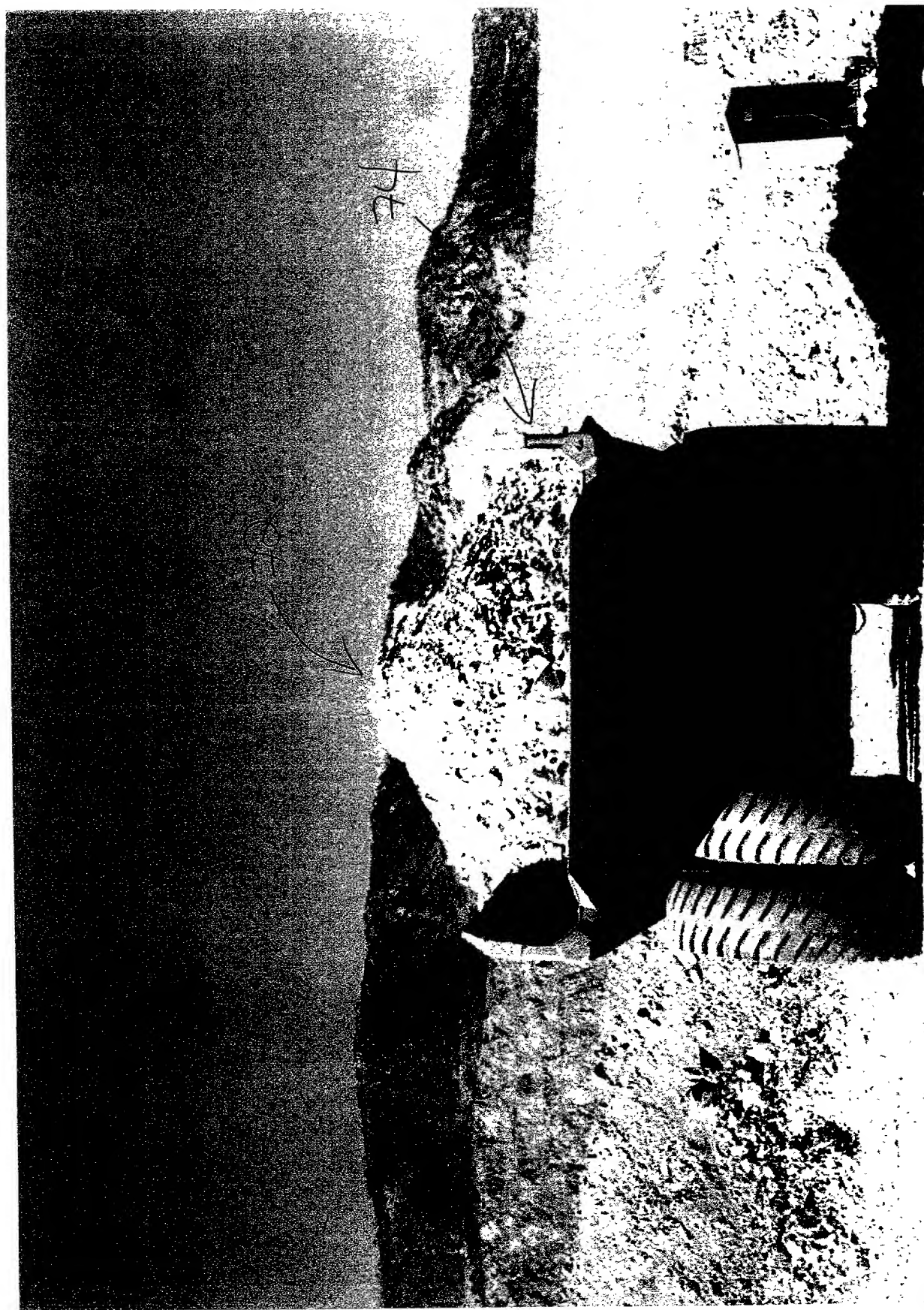


FIG. 22